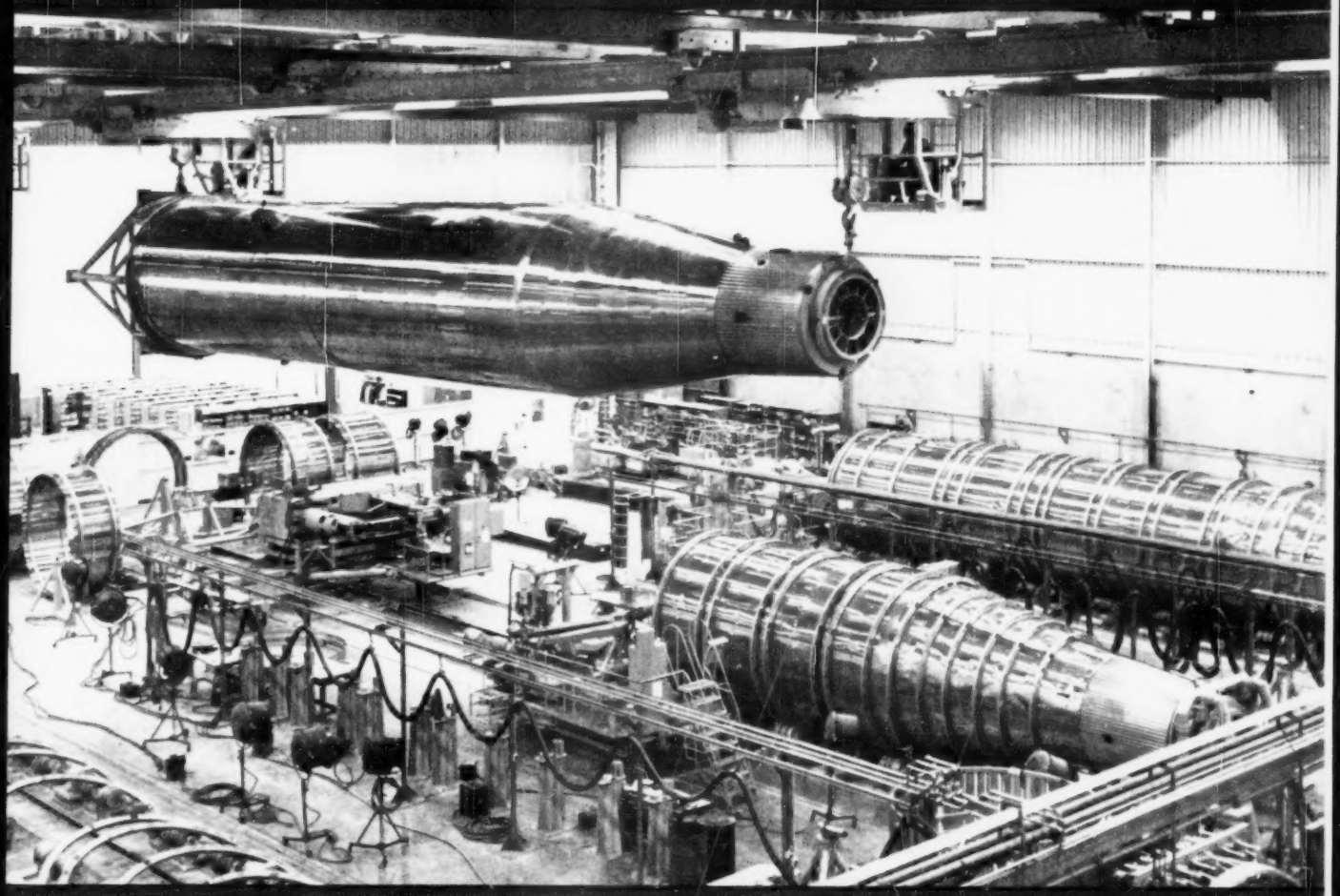
Spaceflight



VOL. III No. 5 SEPT. 1961

CONTENTS

	Page
A PIONEERING MANNED FLIGHT INTO SPACE. George M. Low	134
ASTRONAUT TRAINING. Imbert S. Vos	138
ROCKET RELIABILITY. J. P. Kuettner	152
DESIGNING THE VOSTOK	156
THE PRE-WAR CONTRIBUTION OF THE B.I.S. H. E. Ross	164
THE POST-WAR CONTRIBUTION OF THE B.I.S. A. V. Cleaver	168
RUSSIA'S SPACE PLANS	172
FROM AIRLINER TO SPACELINER. R. C. Truax	173
POSSIBLE OPERATIONS ON THE MOON. Fritz Zwicky	177
CANADIAN SOUNDING ROCKETS	179
EXPLORING VENUS BY RADAR	180
ASTRONAUTICS IN SCHOOL. A. J. Mason	181
QUESTION AND ANSWER	187
CORRESPONDENCE	189

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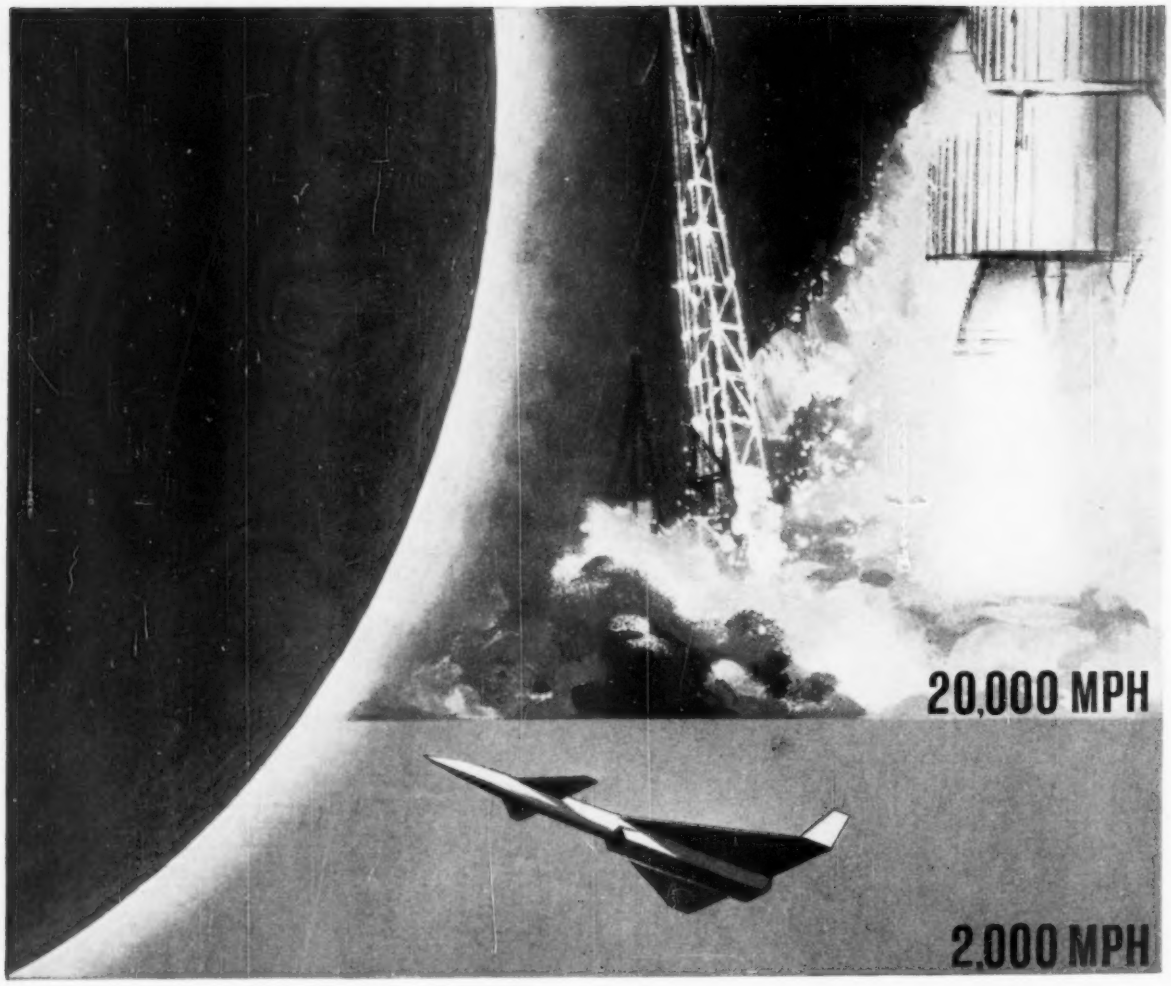

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SPACEFLIGHT

Volume III Sept. 1961 Number 5

THE MAGAZINE OF AEROSPACE SCIENCE AND TECHNOLOGY

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COVER

A Convair Atlas, its thin-gauge stainless steel tanks lightly pressurized with gas, is lifted bodily from the production floor by an overhead gantry. Apart from being America's first operational I.C.B.M., the missile is being increasingly used as a space-booster. It will be used to orbit the Mercury capsule and, as Centaur—with the addition of a LO_2/LH_2 top stage—to establish payloads exceeding 8000 lb. in close-orbit around the Earth.

Convair-Astronautics.

Honouring the Pioneers

On the occasion of Major Yuri Gagarin's memorable visit to this country in July, the World's pioneer astronaut became the recipient of the first Gold Medal to be awarded by the British Interplanetary Society, "in recognition of his achievement of the first manned orbital flight around the Earth." It was presented to him by the Society's president, Dr. W. R. Maxwell, at the end of an hour-long Press Conference at the Soviet Trade and Industry Exhibition at Earls Court on 11 July.

A second B.I.S. Gold Medal for 1961 is being awarded to Dr. Wernher von Braun of the George C. Marshall Space Flight Center of the National Aeronautics and Space Administration. Under the technical leadership of Dr. von Braun, the group at Huntsville in Alabama (formerly under Army aegis) has been responsible for several major triumphs in the United States space programme. These include the first successful American Earth satellite, Explorer I; the first successful lunar probe, Pioneer IV, and the eminently successful Redstone-boosted manned ballistic flights of the Mercury capsule.

The Huntsville group is, of course, heavily engaged on the 1·5 m. lb. thrust Saturn booster, the first firing of which—with dummy upper stages—is expected at Cape Canaveral later this year. Evaluation is also being made of the Nova booster which will form part of America's multi-million dollar programme to land men on the Moon by the end of the decade.

Dr. von Braun's medal will be presented to him during the XIIth Congress of the International Astronautical Federation in Washington in October.

Second Manned Mercury

To Captain Virgil Grissom—America's second astronaut—we extend our warm congratulations. His ballistic flight on 21 July in the capsule Liberty Bell took him to a height of 118 miles and a distance of 303 miles downrange from Cape Canaveral. Despite the mishap at the end of the mission which led to the sinking of the capsule, the flight performance clearly shows the way to the orbital experiments which must now follow.

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A Pioneering Manned Flight into Space

By GEORGE M. LOW*

Men are destined to play a vital and direct role in the pioneering flights around the Earth and to the Moon and planets, for humans are the most versatile scientific instruments yet devised. It is impossible for me to conceive an instrument that could effectively and reliably duplicate man's role as an explorer, a geologist, a surveyor, a photographer, a chemist, a biologist, or a host of other specialists whose talents would be needed.

In all of these areas the ultimate requirement is man's judgement, his powers of observation and reason, his ability to make decisions, and his gift of imagination. Only man can cope with the unexpected, and the unexpected, of course, is what he is most interested in. Indeed, there is no holding him back for man is a born explorer, and flight into space is far too exciting an adventure to miss.

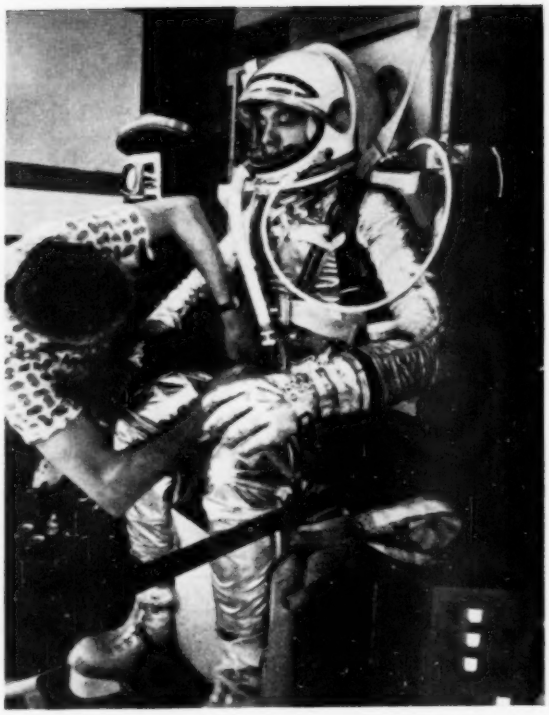
The recent short flight of one of our astronauts is the first of several similar space trips planned in the Mercury programme. They will be followed, after some months, by a number of longer and more difficult Earth-orbiting missions.

Experience gained in the current programme will lead to a more advanced, second-generation craft, already under development. This descendant of the Mercury spacecraft, named Apollo, is being designed to carry men around the Moon and to serve as a complex Earth-orbiting laboratory.

Developing logically out of Project Apollo will be a vehicle capable of landing astronauts on the Moon and planets and establishing a permanent manned space station.

Before we can proceed with the second and third-generation spacecraft, we must know how men react in space, what their capabilities are for performing work, and what must be provided in the vehicle to allow them to function usefully. This is where Project Mercury comes into the picture. From Mercury we expect to discover the answers to these and many other questions. And, equally important, we should learn a good deal about the design, engineering, and operation of the future craft for man's flight into space.

* *Chief of Manned Spaceflight, U.S. National Aeronautics and Space Administration.*



Final adjustments are made to Cdr. Alan B. Shepard's pressure suit on the morning of 5 May.
All pictures United States Information Services.

The flight just completed was intended to subject the astronaut to the high acceleration of a rocket launching, some 5 min. of weightlessness, and the high decleration on re-entry into the atmosphere. On the coming orbital missions the periods of weightlessness will be much longer. In effect, this is like leading a new swimmer into the water gradually, step by step.

To insure that the spacecraft, its delicate inner workings, and its passenger would survive, several years of violent testing preceded the flight. Models and full-scale versions of the craft were battered, burned, vibrated, dropped in the ocean, and generally subjected to terrible beatings before the first one was ever attached to a live rocket. Then they underwent a number of space tests, either empty or carrying chimpanzees.

The Mercury astronauts, all of them highly competent aircraft pilots, were carefully selected and trained more than 2 years for spaceflight. They were trained in laboratories on the ground and in the air to perform tasks under conditions simulating those they would find in space.

Although the first manned flight could have been made without any activity on the astronaut's part, he was given the opportunity to practise some manoeuvres which might be necessary during the later orbital flights. He positioned the craft so that its blunt end re-entered the

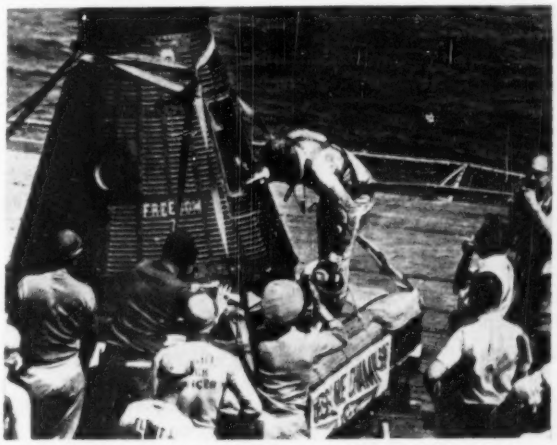
atmosphere first and served as protection against the fierce heat generated by air friction. He fired the retro-rockets which reduced the spacecraft's speed by a small amount. The retro-firing contributed little to the success of this flight, but such action is absolutely essential in bringing an orbiting craft down to Earth. One other practice manoeuvre by the astronaut was his use of hydrogen peroxide jets to keep the craft in its proper position during re-entry.

The man's heartbeat, body temperature, and breathing rate and depth were continuously measured and both recorded in the spacecraft and transmitted to ground control centres, where physicians maintained constant vigil. In addition, the astronaut talked to the men on the ground via radio transmissions.

All told, we are very gratified with the preliminary results of this first manned space test of Project Mercury. The results will be made available to interested, qualified scientists and technologists throughout the world. We truly hope that other nations will join us in developing more advanced spacecraft for the manned explorations of space, which promise not only great adventure but much of value for mankind.

This picture of Cdr. Shepard was obtained during the ballistic flight by means of a 16 mm. colour cine-camera attached to the capsule's instrument panel.

A small 70 mm. camera secured this photograph of the eastern coastline of the United States through the capsule periscope without obstructing Shepard's view.



Having landed some 302 miles downrange from Cape Canaveral, Cdr. Shepard and the Mercury capsule were taken from the sea by a helicopter and deposited on the deck of the aircraft carrier U.S.S. "Lake Champlain." Here Cdr. Shepard inspects the escape hatch.

Astronaut Training

By Dr. ROBERT B. VOAS*

America's first spaceman was, above all, a test pilot. His main job, like that of any other test pilot, was to observe the performance of the vehicle he was flying.

But, on his first Project Mercury spaceflight, he went far beyond the normal functions of his profession, for he was riding an entirely new type of vehicle in the largely unknown environment of space. Though he was experienced in the uncertainties of test flying new aircraft, the short spaceflight taxed the limits of his knowledge, courage, and ingenuity.

He and his six fellow-astronauts, who soon will make their own space trips, underwent more than two years of intensive training covering infinitely more than just the operation of spacecraft controls. During this period, each astronaut found himself alternately in the positions of manual trainee, engineer, scholar, and athlete.

In view of the unusual nature of the Mercury programme, the civilian Space Administration picked sixty-nine military test pilots as candidates because their experience rendered them best qualified for the space venture. The general requirements were: possession of a bachelor's degree or the equivalent in the physical sciences or engineering; graduation from a military test

* *Psychologist, Project Mercury, U.S. National Aeronautics and Space Administration.*

pilot school; 1500 hr. of jet aircraft flying time; under age 40; and 5 ft. 11 in. or less in height.

The sixty-nine were called to Washington to hear about Project Mercury. Eighty per cent. of them volunteered.

The first phase of their training was, in effect, the astronaut selection procedure—a rigorous, two-week-long series of physical, psychological, and stress tolerance tests. In April, 1959, the final seven astronauts were chosen on the basis of each man's combined attributes of experience, intelligence, motivation, and physical and emotional soundness. They were among the best the United States had to choose from as space pioneers.

The astronauts were transferred from their military branches to the civilian Space Administration for full-time duty. Within a few weeks, their training began. It was divided into six areas of activity.

1. *Education in the Basic Sciences.* Essentially an academic educational programme, this area included instruction in astronautics (ballistics, trajectories, fuels, guidance, and other aspects of rocket operations), basic aviation medicine and spaceflight hygiene, the environment of space, astronomy, meteorology, astrophysics, and geography, including the techniques of making scientific observations in these areas.

2. *Familiarization with the Conditions of Spaceflight.* This phase of training familarized the astronauts with heat, pressure, weightlessness, and the tremendous forces of acceleration and deceleration. To simulate the acceleration and deceleration, that is the speeding up of the booster rocket and the sudden slowing of the spacecraft on re-entering the atmosphere, the men were spun in a large centrifuge until pressed back into their couches by a force eighteen times that of their own weight. Aircraft flew them on parabolic paths which made them weightless for nearly a minute at a time. In special chambers, and clad in protective flight suits, they learned to cope with low pressures and extreme heat and cold. The men also learned to perform effectively while whirling crazily in a device that simulated the tumbling of a spacecraft.

3. *Training in the Operation of the Mercury Spacecraft.* Particular emphasis was placed on the use and maintenance of the scientific instruments and the system that controls pressure, temperature, and composition of the air in the cabin. The astronauts also gained a thorough knowledge of the operation and maintenance of the spacecraft and its many component systems, such as communications, attitude control, and retro-rockets.

4. *Participation in the Spacecraft Development Programme.* Each of the astronauts was assigned to a system of the spacecraft as it was being developed into its final architecture. In this way, they acquired a specialized knowledge which they exchanged with each other. The Project Mercury staff made a number of critical modifications on the spacecraft based on suggestions by the astronauts.

5. *Aviation Flight Training.* The men continued flying jet aircraft in order to maintain fine levels of proficiency and decision-making skill in controlling high-performance vehicles. It was felt that these vital abilities would have deteriorated a certain amount had the astronauts confined their training to the ground.

6. *Integration of Astronaut with Ground Support and Launch Crew Operations.* Training in the operation of ground support equipment and observation of rocket launchings provided the astronauts with a good knowledge of what to expect during their own flights.

In addition to this general training programme, the men visited the Cape Canaveral launching site, tracking stations in the Atlantic Ocean area, plants involved in the manufacture and testing of the booster rockets and the spacecraft, and the test area of the X–15, an experimental rocket-powered aircraft which soon will attempt its own manned flight into space.

They witnessed spacecraft recovery operations aboard ships. They practised eating and drinking in the weightless state. And, strangely enough, the astronauts spent much time skindiving, again, to simulate weightlessness, but also to maintain physical fitness.

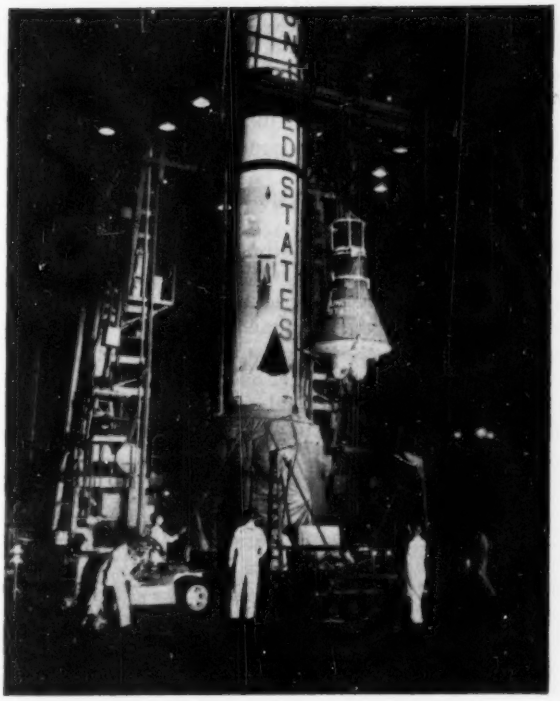
There is little doubt that each of the seven men was prepared for his mission: to ride into space; to control

Cdr. Alan B. Shepard.

the spacecraft; to monitor automatic operations of the craft and report to the ground stations; to navigate; and, most important, to make scientific observations. Prior to the just completed first manned flight, Robert Hotz, editor of *Aviation Week and Space Technology*, concisely expressed the feelings of the seven astronauts and the entire Project Mercury staff when he wrote:

"The aerospace fraternity well understands the hazards involved in man's first attempts at spaceflight, despite all of the intensive training given the astronauts and the best technical efforts to make their equipment sound. Test pilots have stood countless times on the same brink of the unknown, willing to risk their lives in an attempt to advance the technology of man's great effort to leave his Earth behind. Many have paid the full price of their lives in these attempts, and the possibilities of experimental failure always ride with those with the courage to explore the unknown.

"People should understand fully the courage and devotion of the seven astronauts who volunteered for what will probably be the most exciting venture of man in this era."



Preparing for the first manned shot at the Cape. Here the Mercury capsule, "Freedom 7," is being hoisted towards the nose of the Redstone booster.

Rocket Reliability

By Dr. JOACHIM P. KUETTNER*

Development of the Redstone booster began in 1951 at what is now the Marshall Space Flight Centre, one of the facilities of the civilian National Aeronautics and Space Administration. The work was headed by Dr. Wernher von Braun, a German-born rocket pioneer who now is an American citizen.

The first Redstone flight was made on 20 August, 1953, and the second some 5 months later. Since then, more than fifty of the rockets have been launched with such a high rate of success that the Redstone has earned the name of "Old Reliable."

In a modified form, the Redstone became the first stage of the Jupiter C vehicle, which sent America's first satellite into orbit. This satellite, Explorer One, discovered the Van Allen Radiation Belts encircling the Earth. A special long-range version of the Redstone lifted a protected capsule which survived a fiery plunge back into the atmosphere, thus establishing the now common re-entry techniques.

To change the old, field-tested, Redstone into the modern power plant for the Mercury's man-carrying suborbital flights, some 800 changes had to be made in the machine.

To reach the required performance, the tank section was elongated about 6 ft., providing more fuel and liquid oxygen capacity, and adding more than 20 sec. to the burning time.

The rocket engine was modified with major systems changes which have improved its reliability. Its thrust is now 78,000 lb.

A new instrument compartment and spacecraft adapter section were designed. These contain the pressurized instrument compartment located between the fuel tanks and the spacecraft. It does not separate after burnout but remains attached to the Redstone propulsion unit. In it is a less complex control system which used an automatic pilot to control attitude and to reduce drift during powered flight.

A completely automatic emergency sensing system was devised at the Marshall Space Filght Centre. This "abort system" gives an electric signal warning in advance of possible trouble—such as unacceptable deviations in the attitude of the vehicle, excessive turning rates, loss of thrust or loss of electrical power. Any of these will cause the following automatic sequence within a small fraction of a second: termination of thrust, separation of spacecraft from booster, and activation of the escape system which propels it safely away from the booster. The abort system can also be activated manually by the astronaut or by a signal from the Control Centre on the ground.

* *Chief, Mercury-Redstone Project, U.S. National Aeronautics and Space Administration.*

In perfecting the basic design of the Mercury-Redstone launch vehicle, the Marshall Centre conducted special studies, both theoretically and by means of wind tunnel models, to check aerodynamic behaviour. The Centre also prepared the trajectory to be flown on the manned flight and calculated safety conditions over the Atlantic Flight Range.

Literally hundreds of reliability tests were conducted on individual components, systems and sub-systems. The tests covered excessive vibration, stress, atmospheric pressure, humidity and extreme temperatures. The entire top section of the launch vehicle was put into a motion simulator and simultaneously subjected to rigid stress checks to insure that the abort system would operate properly—and not accidentally.

In addition to the normal acceptance firing tests of the rocket engine, the completed vehicle for this manned flight—and for all others in the Mercury series—was captive-fired on the ground prior to shipment to the launching site. Detailed measurements were taken to guarantee proper performance of the engine. In one test, a Mercury-Redstone motor was repeatedly captive-fired for a total duration of fifteen times normal burning time.

In its final test programme for the Mercury flight, the spacecraft and launch vehicle were subjected to compatibility tests, under controlled conditions, to see that each system and sub-system, each section and each part of the vehicle worked in harmony with the others. This sequence of checkouts included simulated countdown, launch and flight. After the first unmanned and animal flights, a number of modifications had to be introduced. They were tested on the ground and during subsequent flights to ensure a reliable flight performance.

Designing the Vostok

Part of the text of an article carried in the Soviet Press on 25 April, giving technical details of the programme which led up to Major Gagarin's historic orbital flight on 12 April, 1961. For the translation, we are indebted to "Soviet News."

The design of the spaceship *Vostok* is based on experience obtained in the launchings of the first Soviet orbital space vehicles.

The satellite spaceship consists of two main components:

The pilot's capsule, with its accommodation for the pilot, the life-sustaining installations and the landing system.

The instrument section with the instruments working during the orbital flight, and the vessel's retro-engines.

After orbiting, the spaceship separates from the last stage of the carrier rocket. In flight its instruments work according to a special programme which ensures taking orbital measurements, transmitting to Earth telemetric information and the televised image of the pilot, two-way radio communication with the Earth, maintenance of the required temperature in the ship and air-conditioning in the pilot's cabin. The instruments are controlled automatically by means of programming devices in the space vehicle or, if necessary, by the space pilot himself.

The programme of the first manned flight was devised for one revolution round the Earth. However, the design and equipment of the space vehicle allows for longer flights.

When the flight programme is completed, a special system orientates the vehicle in space for descent. Then, at a specific point in the orbit, the retro-engine is switched on, which reduces the vehicle's velocity to the calculated value. As a result, the vehicle enters into its descent trajectory.

The capsule with the space pilot is decelerated in the atmosphere. The re-entry trajectory is chosen so that the decleration load on entering the dense layers of the atmosphere will be no greater than the loads permissible for man. When the capsule reaches a specified altitude, the landing system is switched on. The actual landing of the capsule takes place at a low speed. The vehicle travels some 8000 km. (more than 4900 miles) from the moment the retro-engine is switched on till the moment it touches the ground. The descent stage lasts approximately 30 min.

The shell of the pilot's capsule is covered with a heat shield which protects it from burning up during its flight through the dense layers of the atmosphere. The shell of the capsule has three portholes and two rapid-action hatches. The portholes are provided with heat-resistant glass, making it possible for the pilot to conduct observations throughout the entire flight.

The space pilot occupies an ejector seat, in which he remains during the whole of the flight and which enables

him to leave the vehicle should the need arise. The seat is so installed that the load during the orbiting and re-entry stages acts on the pilot in the most favourable direction (chest-back).

In the first flight the pilot wore a protective space suit safeguarding his life and ensuring his working ability even if the hermetic sealing of the cabin broke down in flight.

The satellite spaceship also carried the following systems:—

Instruments and equipment necessary for the vital functions of the human body (an air-conditioning system, a pressure control system, food and water, a system for removing the body's waste products).

Flight control equipment and a system of manual control of the vehicle (the pilot's panel, an instrument board, a manual control system, etc.).

A landing system.

Radio apparatus for communcations with the Earth.

An autonomous system recording the work of the instruments, the radio telemetric systems and various sensors.

A television system for observing the pilot from the Earth.

Instruments for recording the physiological functions of the body.

The retro-engine of the vehicle.

An orientation system.

A flight control system.

Radio systems for orbital measurements.

A temperature control system.

Electricity supply sources.

On the outside surface of the vehicle are mounted the control units, orientation elements, shutters of the temperature control system, and the aerials of the radio systems.

The pilot's cabin is much roomier than the pilot's cabin in an aircraft. The instrumentation of the cabin is designed so as to ensure the greatest convenience for the pilot in flight. From his seat the space pilot can perform all the necessary operations connected with observation, communication with the Earth, and flight control, and if necessary, can control the vehicle without leaving his seat.

The frame of the pilot's seat includes:

A detachable back with a safety belt to hold the pilot in position when catapulting and parachuting.

Parachute systems.

Catapulting and pyrotechnical devices.

An emergency store of food, water, and equipment, and radio means of communication and direction finding for the space pilot to use after landing.

A space suit ventilation system and a parachute oxygen supply unit.

Automatic operation of the seat.

The space pilot can land in the cabin of the vehicle. This method of landing was tested in the fourth and fifth Soviet satellite spaceships with test animals in the cabin. A variant is also provided for in which the pilot is catapulted with the seat from the cabin at an altitude of some 7 km. (about 4½ miles) and is landed by parachute. This variant was also tested in orbital spaceship launchings.

The air-conditioning system in the space vehicle maintains normal pressure and normal oxygen content, a carbon dioxide content of not more than 1%, a temperature of 15–22° C., and a relative humidity of 30–70%. Regeneration of the air—absorption of carbon dioxide and water vapour and injection of the necessary quantity of oxygen—is effected by means of highly active chemical compounds. The regeneration process is automatically controlled. If the amount of oxygen drops and the concentration of carbon dioxide increases, a special sensor gives a signal which alters the operation of the regenerator. If an excess of oxygen is produced a mechanism automatically reduces the amount of oxygen injected into the air of the cabin. The humidity of the air is controlled in a similar way.

A system of special filters is designed to purify the air in case of contamination by harmful admixtures resulting from the functions of the pilot's body and the work of the instruments.

The required temperature is maintained by a special temperature control system. A specific feature of this system is the use of a constant-temperature liquid cooling agent to transfer the heat from the pilot's cabin. The cooling agent flows through the temperature control system to a liquid-gas radiator. The flow of air through the radiator is regulated automatically, depending on the temperature in the descending vehicle. The required temperature is thus maintained with great accuracy.

To keep the temperature of the cooling agent at the required level and to ensure the necessary temperature in the instrument section, an automatic radiation heat exchanger with a system of shutters is placed on the outside surface.

For landing in a designated area the vehicle must be carefully orientated in space before the retro-engine is fired. This is carried out by an orientation system. In the present flight one of the axes of the vehicle was orientated in relation to the Sun. A series of optical and gyroscopic sensors act as the sending elements in this system. Signals from them are fed to an electronic pack where they are transformed into commands governing the control systems. The orientation system ensures with great accuracy the automatic finding of the Sun, adjustment of the vehicle accordingly, and its stabilization in the required position.

When the vehicle is orientated the retro-engine is fired at a specified moment. The commands for switching on the orientation system, the retro-engine and other systems, are issued by an electronic programming device.

The spaceship carried radiometric and radiotelemetric equipment for orbital measurements and controlling the

work of the instrumentation. Trajectory measurements and the reception of telemetric information during the flight are carried out by ground stations in the Soviet Union. The data are automatically relayed along communication lines to computing centres where they are processed by electronic computers. As a result, orbital information is constantly available throughout the flight and it is possible to forecast the further movement of the ship.

The vehicle also carries a "Signal" radio system working on a frequency of 19·995 Mc./sec.

A television system transmits to the Earth images of the pilot and makes it possible to carry out visual observations of his condition. One television camera transmits a full-face view and the other a side-view of the pilot.

Two-way communication with the Earth is ensured by a radio-telephone system working on short waves (9·019 and 20·006 Mc./sec.) and ultra-short waves (143·625 Mc./sec.).

The FM channel is used for contact with ground stations from a distance of 1500–2000 km. (about 930 to 1240 miles). Communications in the short-wave channel with ground stations located in the Soviet Union can, as the experiment has shown, be carried out from the greater part of the orbit.

The radio-telephone system includes a tape recorder for recording the pilot's speech in flight and subsequent reproduction and transmission when the vehicle passes over the ground receiving centres. The space pilot is also provided with a key for telegraph communication.

The instrument panel and pilot's dashboard in the cabin are designed for controlling the work of the main systems and ensuring, if necessary, manually controlled descent of the vehicle. The instrument panel carries a number of dials, light signals, an electric clock, and a globe which revolves synchronically with the vehicle's motion in orbit. The globe enables the pilot to determine his position in flight. The pilot's dashboard carries levers and switches for operating the radio-telephone system and regulating the temperature in the cabin, and also for switching on the manual controls and retro-engine.

In designing the spaceship special attention was paid to ensuring safety of flight. The launchings of the first Soviet spaceships had confirmed the highly reliable working of their apparatus and equipment. Nevertheless, in the spaceship *Vostok* a number of additional measures were taken to preclude the possibility of any accidents and to guarantee the safety of a manned flight. This trend was in full accordance with the basic task—the development of craft enabling man to penetrate outer space with confidence.

In order to orientate the ship when steered manually the cosmonaut uses an optical orientation device to determine the position of the ship in relation to the Earth. This optical device is installed in one of the portholes of the cabin. It consists of two annular mirror-reflectors, a light filter and a latticed glass. The rays travelling from the line of the horizon strike the first reflector and, passing through the glass of the porthole, reach the second reflector, which directs them through the latticed glass to the eyes of the cosmonaut. If the ship's bearings in relation to the vertical axis are correct, the cosmonaut sees the horizon in the form of a circle in his field of vision.

Through the central part of the porthole the cosmonaut sees the part of the Earth's surface directly below him. The position of the ship's longitudinal axis in relation to the direction of flight is determined by watching the "run" of the Earth's surface in the pilot's field of vision.

With the help of the control units the cosmonaut can turn the ship in a direction ensuring that the line of the horizon is visible in the orientation system in the form of a concentric circle, and that the direction of the Earth's "run" coincides with the course plotted on the latticed glass (chart). This will be proof of the correct orientation of the ship. The pilot's field of vision can be covered by the light filter or shutter if necessary.

A globe installed on the instrument panel makes it possible, in addition to ascertaining the ship's bearings during the flight, to predetermine the landing place if the braking device is switched on at any moment during the mission. Finally, the design of the ship allows for landing even if the braking device should fail—with the help of the natural frictional action of the atmosphere.

The supplies of food, water and regeneration substances and the capacity of the electric energy sources are calculated for a flight of up to 10 days.

The design of the ship includes devices preventing the temperature of the cabin from rising above a definite level under the prolonged heating of its surface which occurs during the gradual braking of the ship in the atmosphere.

Bio-Medical Problems

In solving the problem of the possibility of a manned spaceflight and its medical safety, it was found necessary:

(1) To study the influence of the factors of spaceflight on the organism, and also to study possible ways and means of protection against the harmful action of these factors.

(2) To elaborate the most effective methods of ensuring normal conditions for the life of the man in the cabin of the space ship.

(3) To work out the methods of medical selection and training of the members of the crews of spaceships, and also a system of uninterrupted medical control of the pilot's health and capacities throughout the flight.

Each of these questions entailed a large number of particular problems, in the study and solution of which specialists in the fields of physiology, hygiene, psychology, biology and clinical and professional medicine worked uninterruptedly in the course of 10 years. Research was carried out in laboratories on Earth and during the

flights of animals in rockets. The rich experience accumulated in the fields of applied physiology and medicine, particularly the medicine of aviation and underwater swimming, was taken into account. Whereever possible special stands were set up for the laboratory study of the action of spaceflight factors on the organism. The influence of various strains and the organism's reaction to them were studied in centrifugal machines which reproduced accelerations analogous to those occurring during the periods of boosting and recovery.

With the help of vibro-stands, thermo- and vacuum-chambers and similar units, the action of other factors on the organism was studied. However, the laboratory experiments, as a rule, could furnish answers only with regard to the action of any particular one of these factors on the organism, whereas during a real flight in a rocket these factors act simultaneously and in combination. Besides, the behaviour of living organisms in the condition of weightlessness could not be studied in the laboratory. Therefore the biological research carried out with the help of rockets, beginning with 1951, brought us considerably nearer to a study of the influence of the conditions of spaceflight on the organism.

Several dozen experiments were made on animals which ascended to altitudes of up to 450 km. (about 280 miles) in rockets. As a result, comprehensive scientific data were accumulated describing the reaction of the physiological systems and the behaviour of the animals (dogs, rabbits, rats and mice) at different times during the flight. A careful examination of the test animals both during the flight and during a prolonged period after their return to Earth allowed us to draw the conclusion that living organisms withstand the conditions of flights in rockets to the upper layers of the atmosphere quite satisfactorily. The changes observed in some of the physiological functions during the flight were not of a morbific nature; quite often they disappeared while the experiment was still in progress and did not reappear subsequently.

However, owing to the short duration of rocket flights there was no possibility of studying the biological effects of such important factors of spaceflight as prolonged weightlessness and cosmic radiation. Therefore, the opportunity of using artificial Earth satellites for biological experiments which became possible in 1957 was an exceptionally important step forward.

The first such experiment was conducted on the second Soviet sputnik. It not only confirmed but augmented the data on previous biological experiments on rockets. It was proved for the first time that a prolonged state of weightlessness, as such, does not violate the basic vital processes.

Biological experiments were continued in the first Soviet orbital spaceships. The programme of this medical-biological research included a number of new problems. Besides an additional and a more thorough study of the influence of prolonged weightlessness on the organism, of great importance was the study of the transitional condition from weightlessness to overstrain and vice versa, and thorough research into the biological effects of cosmic radiation.

An important part of the programme was also the study of the peculiarities of the operation and effectiveness of systems which in future flights should ensure normal conditions for man's vital activity and guarantee his safe return to Earth. In carrying out the planned programme, diverse representative specimens of the organic world, from the simplest forms of life up to higher vertebrates, were placed in the first Soviet orbital spaceships.

The utilization of various species of animals and plants for experiments made it possible to study very thoroughly and in great detail the influence of the conditions of spaceflight on the most diverse processes and functions of organisms. Data on the behaviour and physiological functions of experimental dogs during flights were especially widely provided. The behaviour of animals was observed with a special television system. An analysis of the data obtained showed that the animals not only fully retained their vital activity under conditions of the protracted effect of weightlessness and the following influence of overstrain, but that no morbid symptoms were discovered in the condition of their main physiological functions. A sufficiently prolonged and careful investigation of the animals after flight also did not reveal any deviation whatsoever from the normal.

Particularly serious attention was devoted to detecting any possible effects of cosmic radiation during the flight of an orbital spaceship. The numerous methods used for solving this problem did not reveal changes which could possibly have been caused by ionizing radiation.

The results of the medical-biological research conducted in orbital spaceships made it possible to draw exceedingly important and crucial conclusions. It was acknowledged that flights in orbital spaceships, admittedly circling lower than the radiation belts nearer to the Earth, are safe for highly organized representatives of the animal kingdom. The results of the biological experiments were used for solving the problem of safe manned flight.

These, along with laboratory investigations, led scientists to the conclusion that man's flight into space would not be detrimental to his health.

The first spaceflight could only be performed by a man who, realizing the tremendous importance of the task set him, had consciously and voluntarily agreed to give all his strength and knowledge, and perhaps even his life, to the accomplishment of this oustanding exploit. Thousands of Soviet citizens, patriots of their country, of widely varying ages and professions expressed the wish to make the flight into outer space. Soviet scientists were instructed to carry out a scientifically well-founded selection of the first cosmonauts from among the vast number of applicants.

In the course of a spaceflight man is subjected to the influence of a whole complex of environmental factors

(acceleration, weightlessness, etc.) and a considerable nervous and emotional strain calling for the mobilization of all his moral and physical abilities. Along with this the cosmonaut must retain a high degree of working ability and be able to orient himself in the complicated conditions of the flight and, if need be, take part in controlling the spaceship. All this determined the high demands made on the cosmonaut's health, his psychological qualities and the level of his general background and technical proficiency.

These qualities are most fully combined in pilots. Work as a pilot already determines the stability of a man's nervous and emotional sphere and his strong willpower, which are of particular importance in the first spaceflights. In the future the range of persons taking part in such flights must undoubtedly be broadened considerably.

In recruiting the group of cosmonauts, there were talks with a great number of pilots who had expressed the wish to make a spaceflight. Those of them who were most suitable were subjected to a careful clinical and psychological examination. The purpose of this examination was to determine the state of health, reveal the latent deficiency or reduced resistance of the organism to individual factors characteristic of the future flight, and ascertain reactions to the action of these actors.

The examination was carried out with the use of a number of modern biochemical, physiological, electrophysiological and psychological methods and special functional tests making it possible to assess the reserve possibilities of the main physiological systems of the organism (investigations in the pressure chamber at considerable degrees of rarefication of the air, during abrupt changes in the barometric pressure and the breathing of oxygen at increased pressure, investigations in the centrifuge, etc.).

An important stage came with the psychological investigations, designed to seek out persons possessing an especially retentive memory, resourcefulness, keen attention that can easily be switched from one thing to another, and the ability to make precise co-ordinated movements speedily.

As a result of the clinical physiological examination a group was formed who set about carrying out the programme of special instruction and training on special stands and devices simulating conditions of a spaceflight on the ground and in the air. Simultaneously the individual peculiarities of the organism's reaction to the effect of simulated factors were ascertained.

The programmes of special instruction were designed to supply the cosmonauts with the necessary information on the basic theoretical questions connected with the forthcoming flight, as well as practical skill in the use of the equipment and instrumentation of the spaceship's cabin. This programme provided for the study of the fundamentals of rocket and space techniques, the design of spaceships, and special problems of astronomy, geophysics and space medicine.

The programme of special training and tests included:

Flight in aircraft in zero-gravity conditions.

Training in a replica of the spaceship cabin and on a special training device.

Prolonged spells in a specially equipped sound-proof chamber.

Training in the centrifuge.

Parachute jumps from aircraft.

In the process of special training certain problems of ensuring manned spaceflight were also solved, in particular those connected with the feeding of the cosmonaut in flight, his space suit and the system of air regeneration.

During the flights in planes the individual reactions of the cosmonauts during weightlessness and transition from weightlessness to overstrain were studied. The possibility was studied of maintaining radio communication, taking water and food, etc. This provided answers to some important questions about man's possible actions in spaceflight conditions.

It was found that all the cosmonauts who had been selected endured zero-gravity well. Besides, it was established that in a state of weightlessness lasting for up to 40 sec. they could normally take liquids, semi-liquids and solid food, perform intricate co-ordinated acts (writing, purposeful movements of the hands), maintain radio communication, read and orient themselves visually in space.

Training in the replica of the spaceship's cabin and in the special training device was designed to enable the cosmonauts to study the equipment and instrumentation of the cabin, practise the procedures of the flight task and accustom themselves to being in the cabin of the actual spaceship. For this purpose a special training stand was created with electronic devices with the changes taking place during the real flight being simulated on the instruments. The pilot acted just as he would in space. An opportunity was provided of simulating unusual (emergency) versions of the flight and training the cosmonaut to act in such circumstances.

The main task of the investigations conducted during prolonged stay in the specially equipped sound-proof chamber was to establish the nervous-psychological stability of the cosmonaut during a prolonged spell alone in the isolated, closely confined cabin, with a considerable reduction of external irritants. In the course of this training the routine and feeding processes of a real flight were simulated.

A wide range of physiological tests and special psychophysiological methods made it possible to single out the individuals possessing the best characteristics for accuracy and for precision in fulfilling assignments, and also those possessing a stronger nervous and emotional system.

Training on the centrifugal machine and in the thermal chamber tested the cosmonaut's endurance of corresponding effects, the influence of these effects on the basic physiological functions was studied, and questions

concerning increasing the stability of the organism to external surroundings were decided. As a result of the tests it was established that the cosmonauts possessed good stability as regards the influence of these factors and individuals were singled out who stood the tests better than others.

During the course of air-drop training each cosmonaut had to make several dozen jumps. The physical training of the group of cosmonauts consisted of planned sessions and setting-up exercises. The planned sessions were based on the individual features of each cosmonaut's physique. The setting-up exercises, conducted for an hour daily, were aimed at general physical training. The physical training sessions were directed at improving the stability of the organism to the effects of acceleration, working out and perfecting how to use the body with ease in space, and increasing the ability to endure prolonged physical strain.

Physical training was conducted under constant medical observation and combined specially selected exercises, games, diving, swimming and exercises on special apparatus.

The direct preparations for the forthcoming spaceflight were organized when the special training programme had been fulfilled. These preparations included:

Study of flight assignments and the maps of the landing area, instructions in piloting, conducting radio communication, etc.

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The Pre-war Contribution of the B.I.S.

By H. E. ROSS, F.B.I.S.

In the autumn of 1936—that is, before transfer of B.I.S. Headquarters from Liverpool to London at the end of 1936—a Technical Committee was established to study the problems associated with structural design, payload composition and navigation of a spaceship provisionally capable of making a round trip to the Moon. The decision to embark on such an ambitious programme rather than confine activity to bigger and better rockets, lay in the fact that, as an *interplanetary* Society, a prime function of the B.I.S. must be to try to prove in a more convincing manner than hitherto that space could be crossed. In any case it was felt that only by attempting a detailed embodiment was it possible to determine what problems remained to be solved.

Later, in 1937, an Experimental Committee was also set up, inadequately financed but charged with the task of developing a few ideas which had arisen out of Technical Committee discussions. As these two Committees consisted mainly of the same people, it will serve if I give the names of those first enrolled as members of the Technical Committee, as follows:—

J. H. Edwards, Research Director

Bramhill.	A. Janser.
A. C. Clarke.	Klemantaski.
A. V. Cleaver.	H. E. Ross.
M. K. Hanson.	R. A. Smith.

I much regret that I cannot remember either Bramhill's or Klemantaski's initials—in the case of Klemantaski because I cannot recall which of the two brothers of that name was on the Technical Committee. I should also remark that other people were co-opted from time to time, two of these being Richard Cox Abel and J. G. Strong.

As design of the spaceship proceeded, certain problems arose which necessitated special studies by members of one or other of the two Committees. For example, the need for more energetic fuels led to a joint investigation by research chemist Janser and Edwards. Some eighty fuel combinations were studied, and of these about thirty were said by Edwards to have been submitted to superficial practical test on a laboratory scale. However, since detailed evaluation of the results does not exist, it is impossible to judge the degree of success obtained. Janser's *Journal* article December, 1937, entitled "A Contribution to the Fuel Problem," discussed the relative merits of liquid and solid fuels and introduced the intermediate concept of colloidal suspensions containing a light metal such as magnesium or aluminium.

First part of a two-part lecture given before a meeting of the British Interplanetary Society on 6 May, 1961.

However, no practical follow-up of this line of approach was possible owing to lack of money and facilities.

The cardinal need to reduce dead-weight led to experiments aimed at producing a lightweight primary battery to serve as the spaceship's source of electrical power. A reaction employing magnesium as one electrode was tried, but results were not encouraging and further work in this line was deferred pending a reassessment of possibilities.

An entirely original line was struck with a decision to attempt the design and construction of inertial navigation instruments—an inertial altimeter, an inertial speedometer, and inertial accelerometer. It is probably unnecessary to remark that navigational instruments of this genre have since been successfully developed and used with pin-point precision in rockets, aircraft and submarines. However, for the pre-war B.I.S., development of such devices was foredoomed to failure. Money, precision engineering facilities, time—all were lacking. For these reasons the very simplest approach had to be adopted, involving in the case of the altimeter nothing more complicated than a flywheel, weight and spring

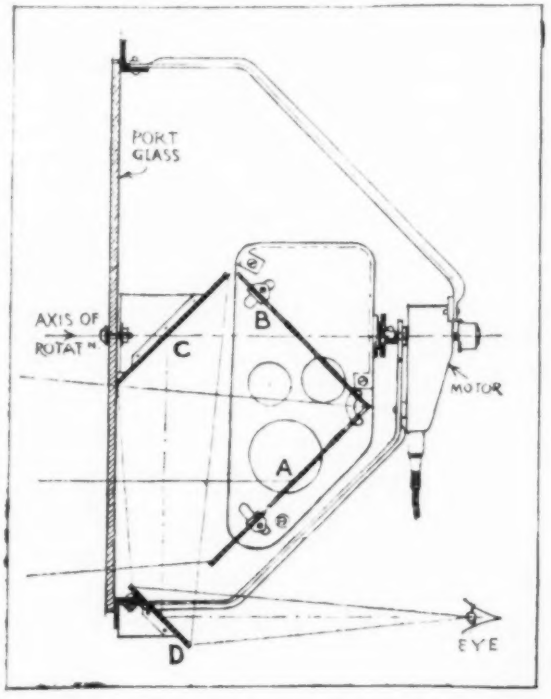


FIG. 1. Diagram illustrating principal features of the Coelostat.

combination. Even so, the engineering niceties proved insurmountable, and little progress had been made up to the time when outbreak of war caused suspension of activities. A fairly detailed description of the proposals remains in the January, 1939, *Journal*.

"The Payload on the Lunar Trip" was discussed in an article by Maurice K. Hanson in the January, 1939, *Journal*. It summarized the views of the Technical Committee, and is probably the most detailed account of requirements up to that time.

A little liquid oxygen was envisaged for spacesuit and emergency use, but the foreseen difficulty of storing liquid oxygen for the 20 days of a round trip to the Moon by three men led to the proposal to take 500 lb. of concentrated hydrogen peroxide as the source of oxygen for breathing. The strength was to be such as to yield sufficient oxygen plus 3 pints of water per man/day. This proposal is remarkable because it was made without the knowledge that stable highly concentrated hydrogen peroxide could be made in bulk—as was however actually being done in Germany at that time. The practicability was simply taken for granted as a reasonable technical development of laboratory scale possibility. The other problems of air-conditioning were not thoroughly explored beyond mention that soda lime or some other suitable chemical would be able to remove respired carbon dioxide and excess water vapour.

Food was to be chosen for energy yield rather than protein content, and sweet cocoa was to be the main beverage. The necessary minimization of payload weight reduced such things as culinery utensils, dishes and cutlery to bare necessities, and even the "medicine chest" was drastically skimped for the same reason. There was also to be a "repair kit," but little detail was given beyond a remark that a spacesuit puncture repair outfit would be needed.

A list of navigational equipment extra to the inertial instruments comprised optical sextants, an optical range-finder, and a chronometer. These would have been useful on the Moon as well as during the transits. Other ancillaries noted were such things as reference books, almanacs, mathematical tables and notepaper—all printed on thin ricepaper in order to save weight. For the same reason, balsa wood pencils were proposed.

The need to save weight was again reflected in the tentative proposal to use relatively simple photophone gear for communication with Earth rather than radio—directional microwave radio being then in its infancy and its ability to penetrate the ionized layers of the atmosphere unknown. The disadvantage that communication would probably be limited to intercourse during darkness at the Moon and Earth terminals, with a clear sky at the terrestrial end, was appreciated and accepted pending further thought.

Miscellaneous equipment for use on the Moon included the following: dynamite for seismic experiments, spades, geological hammers, microscope, specimen tubes, spring balance for gravity measurements, camera and cine-camera and photographic chemicals. A light canvas tent was also to be taken. This was to be used as a thermal barrier, either over the inhabited spaceship or over crew and their equipment when camping.

Another device, accountable in the payload and not yet mentioned, deserves more than a passing reference—the instrument, or instruments, needed to provide a means of observation from a spaceship gyroscopically stabilized by rotation about its long axis and furnishing a gravitational datum for the crew and any loose objects inside the cabin. In this connection, it should be remembered that in pre-war days the ability of human beings to remain in full possession of their mental and motor faculties under zero gravity was unknown. It was not only unknown but commonly sited as a possibly serious bar to spaceflight of any worthwhile duration.

Use of suitably adapted television was considered, but the equipment weight looked formidable. There was also the navigational disadvantage that, unless much refined, stars could neither be seen nor photographed by this means.

The simple optical device actually adopted, and called a *Coelostat*, was invented by Edwards, made by R. A. Smith, described by him in the July, 1939, *Journal*, and demonstrated at the Science Museum, South Kensington, on 7 March, 1939. So far as is known, this was the first instrument ever devised specifically for use in a spaceship.

Upon reference to the drawing (Fig. 1), it will be seen that the Coelostat consisted of two fixed plane mirrors, C and D, serving as a periscope, and a pair of rotating plane mirrors, A and B, set at 90° to each other and at 45° to the axis of the ship. As this pair of mirrors rotate the scene through twice the angle at which they themselves rotate, they furnish a stationary view when spun at half the speed at which the ship is rotating. For purpose of demonstration, a wooden disc (actually the top of the Smith family's coffee table) with large letters B.I.S. painted on it, was revolved by an electric motor. On looking at this disc through the Coelostat, also driven by an electric motor, one had the somewhat awe-inspiringly science fictional sight of the room revolving round a stationary disc.

It was proposed to point the Coelostat through the "nose" of the cabin, the eyepiece being located in some convenient position. Turning the ship bodily by means of auxiliary jets would permit observation, and photography, in any direction. A second Coelostat pointing rearwards was visualized for use during lunar approach manoeuvres, with the ship still spinning. However, just prior to touchdown spin would be cancelled and the landing monitored by direct viewing through lunettes in the overhang of the cabin floor.

Another type of Coelostat, in essence rotating double-sided plane mirrors, was proposed to enable a stationary view to be obtained from the portholes in the side of the cabin. These can be seen in Fig. 3. But this version would have needed a complex optical system, and, being rather superfluous, was not developed.

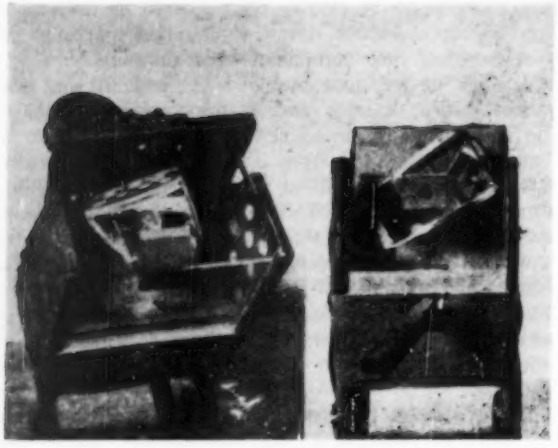


FIG. 2. Mock-up of the Coelostat as demonstrated at the Science Museum, South Kensington, in 1939.

Early in 1939 a small rocket proving stand was designed and made by R. A. Smith, as the outcome of discussions by the Experimental Committee. An article by R. A. Smith describing this piece of equipment appeared in the March, 1939, *Bulletin*; however, no actual tests had been made up to the time when outbreak of war forced a suspension of activities.

The foregoing studies by the Technical and Experimental Committees contributed to the spaceship design which was going ahead concurrently. Fig. 2 shows how much progress had been up to January, 1939, when these drawings by R. A. Smith and a description by H. E. Ross appeared in that month's *Journal*.

It will be seen that a novel constructional approach had been adopted, in that besides splitting up the ship into the usual few "steps," each step was further subdivided into a honeycomb formation comprising numerous individually complete solid fuel rockets, each of which consisted of a cylindrical fuel chamber and a venturi, with a stipulated burning time of 60 sec. This idea, originated by Edwards and developed in practical form by R. A. Smith, was a major advance over previous conceptions. Firstly, instead of having to wait until a whole *step* had become exhausted of fuel, "dead-weight" could be jettisoned piecemeal, at very short intervals of time. This not only greatly reduced the overall weight at launch but also substantially improved performance. Indeed, whereas up to that time the launch weight of a round trip Moonship was frequently assessed at hundreds of thousands of tons, the 130 ft. high and 20 ft. diameter B.I.S. ship weighed only 1000 tonnes.

Secondly, "cellular-step" construction permitted control of thrust—if greater thrust was needed extra units could be ignited; if less thrust was needed the frequency at which new units were ignited could be reduced. This proposal does in fact seem to be the first practical suggestion for controlling the thrust of large multiple rockets using solid fuel. Manifestly, however, a similar scheme could be used for the same purpose with multiple liquid fuel units.

Two reasons combined to base the design on solid fuel units. In the first place, Edwards' natural inclination to originality automatically set him against the vogue of liquid fuels, despite their acknowledged higher intrinsic energy. The second reason was the combined one that solid fuel rockets were undoubtedly more reliable, far less complex, less likely to be adversely affected by ambient thermal variations, and—above all—simpler to incorporate in the tentative design study which was engaging attention. In other words, adoption of solid fuel units avoided all the problems and uncertainties associated with, for instance, such things as fuel pumps, valves and plumbing. Less realistic was the assumption that a solid fuel capable of yielding an exhaust velocity of 3·4 km./sec. in the case of the largest units and 3·7 km./sec. in the case of the smaller units could ultimately be produced. Failure to achieve this would of course seriously affect the launch weight. However, as a principle, cellular-step construction does seem practically advantageous for chemically propelled interplanetary vehicles.

Proceeding now to details, we may begin by remarking that the largest rocket units are each 15 ft. long and 15 in. in diameter. There are 168 of them in each of the first five steps. Step 6 comprises 450 medium size and two tiers of 600 small units. This adds up to a total of 2490 units.*

The units of each step are held in position by light webs and sliding release bolts, so that they are free to drop off directly their thrust ceases—that is, at all-burnt. A light sheath surrounds each step. This contributes to structural stability and also acts as a heat shield. Webs and sheathing jettison progressively as they become free to do so.

As will be seen from the drawings, the ship's body is hexagonal in cross section as the result of the honeycomb stacking formation. The hexagonal compartment between the sixth step and the cabin contains six sets of liquid fuel rockets arranged in arcs at the corners. Concentrated hydrogen peroxide was tentatively assumed. These motors are the fine control mechanism, used principally for turning the ship bodily and for lunar landing manoeuvres. Four of the tangential jets for control of spin, and hence stability and "artificial gravity," can be seen at the top of this compartment, in which there are also two air locks for entry and egress from the cabin. One of the four oil-buffered landing-legs is shown. These were to be uncoupled and left behind as the ship rose from the Moon.

Only a few of the many items of equipment are shown. Most of the gear and stores was to be housed in the compartment under the cabin. The main 10 kW.

* *The July* 1939 *"Firing Control" article states that there are* 45 *medium tubes, and the total number of tubes is given as* 2250. *This was an error on my part (H.E.R.).*

power-pack was to be housed in the drum-shaped box straddled by the cabin roof supporting structure. To these struts is attached a circular handrail for use when walking about. The circular walkway can also be seen. Forward and side-view ports, together with the rear-view lunettes, can be seen. All these were to be fitted with double glass and air-tight shutters; however, last thought on this subject was that the viewing ports should be as few and as small as possible.

Three radial couches are seen—remarkably enough, body-contoured in the approved modern style. Most important manual controls were to be on panels adjacent to or actually part of the arm rests. The couches were to pivot to provide automatic adjustment to the current gravitational datum; in addition, they were to be set on rails, so that they could be moved at will to different positions round the cabin.

Whipple is usually credited with post-war invention of the "meteor-bumper." However, in fact, the cabin of the B.I.S. ship was to be double-walled, for the dual purpose of preventing the penetration of small meteors and improving thermal insulation. Unfortunately the drawings do not show this feature, as they were completed before all details had been settled. Unfortunately, too, I forgot to mention this innovation in my original article. My recollection of Technical Committee discussions on the utility of double-walling is however confirmed by A. V. Cleaver.

Protection against frictional heating during the ship's ascent through Earth's atmosphere was to be afforded by a radially segmented and discardable 2-ton reinforced ceramic carapace. This was probably more thermal protection than would have been needed, for the maximum acceleration at any stage of the flight was to be restrained to 3 *g*. Though sacrificing *g*-loss and therefore overall performance, this value was at least known to be a not unreasonable imposition on the faculties.

It will be noticed that the carapace is not sharply pointed but blunt. This remarkably foresighted innovation envisaged that it would function partly as a heat sink and partly by ablation.

The ship was calculated to an overall velocity performance of 25 km./sec.—theoretically enough for the lunar round trip; but only marginally so, even taking into account that every non-essential item of equipment, stores and instruments was to be left on the Moon. The last of the solid and liquid fuel would be expended in slowing the ship for descent through Earth's atmosphere; the whole of the structure remaining below the cabin would then be jettisoned, and the parachute (not

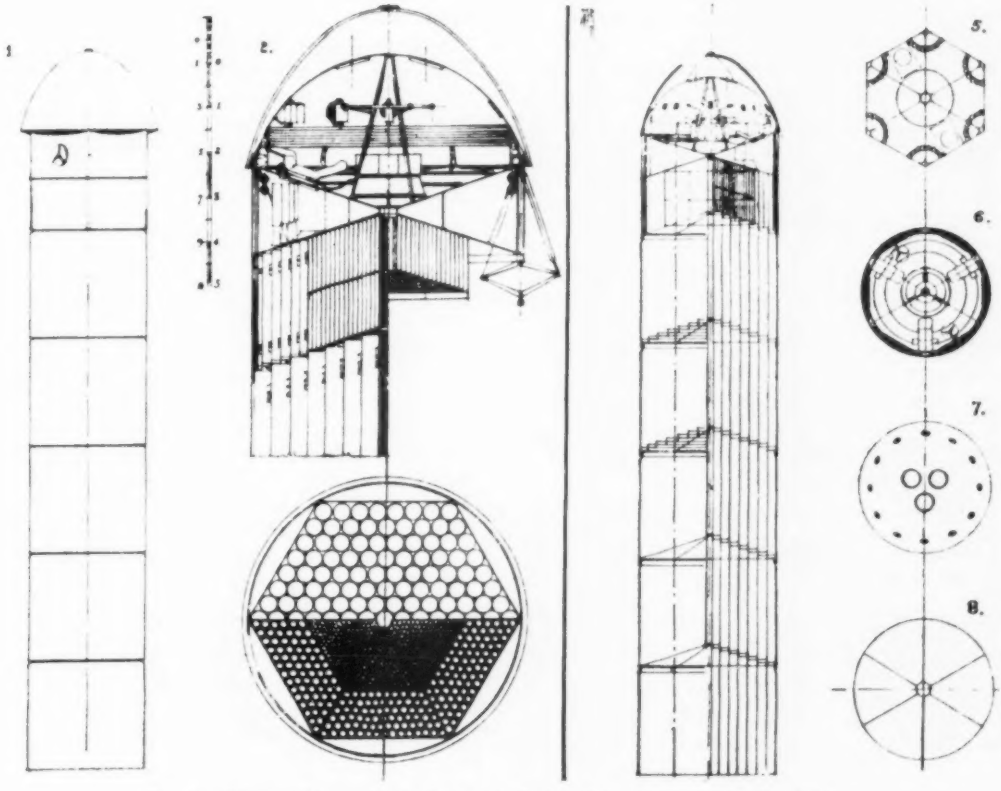


FIG. 3. Diagrams drawn by the late R. A. Smith of the pre-war B.I.S. Spaceship.

shown in the drawings) would be sprung. A descent into water was envisaged, with the parachute detaching just before touchdown.

The July, 1939, *Journal* contained an account by Edwards and the present writer of the system to control ignition of the solid fuel motors. Automatic programming was provided by means of banks of selector switches coupled to the accelerometer, a gyroscope and a pendulum; but manual control could be assumed immediately by any one of the crew, should need arise. A conduit down the centre of the ship carried all the ignition wires.

The January, 1939, *Journal* article ends with a remark that a "launching device" was envisaged, and that this would be discussed in a subsequent issue. However, war intervened, and the complementary article was not written. The proposals were, nevertheless, referred to by R. A. Smith in a lecture to the B.I.S. on 27 April, 1946, which was published in the June, 1946, *Bulletin*. A more complete account follows, in which a remarkable similarity to *Polaris* may be noted:—

The B.I.S. ship was to be launched from a flooded rotating caisson submerged in water. High pressure steam was to be injected into the caisson to start the vehicle upwards, and almost immediately afterwards 128 of the first-step rockets would be ignited. Quoting Smith, the main idea behind this was that floatation would "distribute the load over a greater area."

The launching site was to be a large body of water situated at high altitude as near as possible to the Equator. Several reasons were behind this proposal. Firstly, maximum advantage of the Earth's rotation would be obtained at the Equator. Secondly, a high altitude start would cut down air resistance loss and reduce frictional heating. Thirdly, the ship would weigh a little less at high altitude. Fourthly, a large body of water could be more easily sequestered and patrolled than a range-head on land. Fifthly, less damage to the surroundings would ensue in event of explosion.

Most favoured launching site was the Andean Lake Titicaca, partly in Bolivia, partly in Peru, and centred on about 16° South latitude. This lake is at 12,500 ft.; its area is some 3200 sq. miles; there is a wide range of depths and numerous islands; and it is accessible by railway from the Pacific coast.

* * * * * * *

I think I am justified in saying that the foregoing review of the principal work of the pre-war B.I.S. Technical and Experimental Committees reveals that original thinking was done, and that worth-while contributions to astronautics were made. How much of it has been independently reinvented, or will be independently reinvented, and used, is for time and future historians to decide. Indeed it is possible that some of the items for which I claim B.I.S. origin were actually invented by other groups or individuals before the period I have covered. All I can say is that I have no knowledge of any such priority. Summing up the feasibility of the B.I.S. proposals for cellular-step construction in particular, and especially in view of recent advances in solid fuel rockets, I myself believe that we may yet see something like it—probably using a mixture of liquid and solid fuel units. Indeed, if one looks at the solid fuel second, third and fourth stages of, for instance, Pioneer IV and Explorer, we find a small-scale form of cellular-step construction actually used. And the march of time has seen great advances in the specific impulse and mass-ratio of solid fuel rockets. For example, stage 3 of the *Scout* rocket is stated to have a Specific Impulse of 261 and a mass-ratio of 10:1. It is also interesting to note that the single unit fourth stage of solid fuel *Scout* has a diameter of 18 in.—3 in. more than the diameter of the B.I.S. ship's largest unit. That, pre-war, to all but perhaps B.I.S. technicians, would have been laughed to scorn as impossibly big. And, I venture to guess, even pre-war B.I.S. technicians would have hesitated to acknowledge a belief that solid fuel units 63 ft. long, 14 ft. in diameter, thrust 2·4 million lb., 82 sec. burning time, would ever be practicable. Yet according to, for instance, *Electronics*, 27 January, 1961, such units are under study by the Redstone Division of Thiokol Chemical Corporation for N.A.S.A. It is further stated that it is proposed to cluster seven of these units to power the first stage of future space research vehicles. Nor is this the biggest solid fuel unit seemingly contemplated, for mention is made of a unit 28 ft. in diameter—8 ft. more in diameter than the whole base of the B.I.S. ship! As for the 1000 tonnes launch weight, this is remarkably modest when set against von Braun's 7000-tonners.

Truly, whilst the *possible* takes a little while, the *impossible* takes only a little longer. In the case of the B.I.S. Moonship, I for one conclude at this later and more potent date, that whilst it never flew off the drawing board, its lineal descendents may well do so. If not, then in writing its epitaph, we can at least say: "*If not true, it was well invented.*"

The Post-war Contribution of the B.I.S.

By A. V. CLEAVER, F.R.Ae.S., F.B.I.S.

The views expressed in this paper are my own—not necessarily those of the Society, or its Council. I was invited to talk about the post-war *technical* contributions of the B.I.S., but I have not chosen to interpret this instruction too literally. It is undesirable—indeed, I believe it is impossible—to separate rigorously the technical, philosophical or ideological, political, and educational aspects of astronautics.

Before World War II, the B.I.S. was a small group of enthusiasts and cranks. I was one of these myself, having joined in 1937, four years after the Society was founded; modesty forbids me to say which. The membership never exceeded 100 in those days; quite sound technical suggestions were made, as Harry Ross has shown. The importance of staging, with the limitation of chemical propellents; the possibilities of colloidal solid propellents, with metallic additives; the vast promise of nuclear energy; water-borne launchings, even from high altitude (Lake Titicaca); inertial navigation and instrumentation generally—all these were considered and discussed intelligently, together with heat shields and many other surprisingly "modern" features.

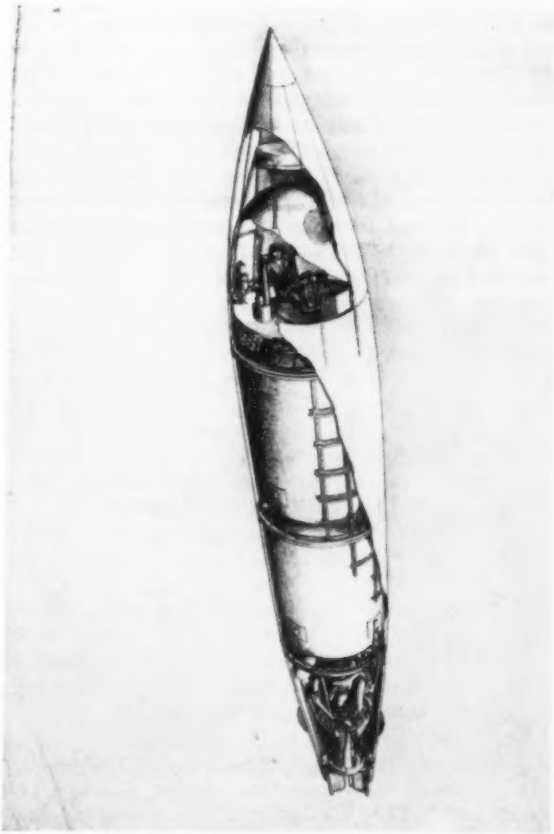
If the pre-war B.I.S. had any noteworthy shortcoming, it was a failure to appreciate realistically the huge resources which would be necessary to realise the ancient dream of space travel. This, at the time, was surely forgivable. An example was a pre-war pamphlet authored by Arthur Clarke, which claimed that the cost of a single destroyer would pay for a lunar spaceship. (The U.S. President has just told Congress that it will probably cost £10,000,000,000, spread over a decade, to send an American expedition to the Moon before the Russians.)

Since the war, it has been one of the main contributions of the Society to atone for this early optimism, and present the whole subject in a more realistic public perspective.

During the war years, many of the more active B.I.S. members, such as Ralph Smith, Harry Ross, Arthur Clarke, myself and several others kept in touch. Contact was also established and maintained with the other, smaller, British groups of space enthusiasts, led by Eric Burgess (now settled in California and working in the new aerospace industry), and Ken Gatland (still well known to us in the U.K.). A combined society, under the old name of the British Interplanetary Society, was re-formed on 31 December, 1945.

In my following remarks, I shall concentrate on the decade from 1946 to 1955, inclusive, because I believe this to have been, in the Churchillian phrase, the "finest hour" of the B.I.S. I do not say this, of course, in the sense that I believe the B.I.S. has no further significant contribution to make; far from it—very far from it. However, it was during this period that we had the chance to make a unique contribution—and I think that, in large measure, we rose to the occasion. Such an opportunity may not arise again.

The war years had brought the developments of ballistic missiles, aircraft and jet propulsion, radar and nuclear energy. Public opinion was much more susceptible to the argument that such further applications of science as space-flight were both feasible and desirable. The B.I.S. exploited (in the best sense of this word) this situation, at a time when other organizations were still



The Smith/Ross man-carrying rocket, conceived in 1946 for performing a similar mission as today's Mercury-Redstone. The design was based on an enlarged and up-rated German V-2.

Second part of a two-part lecture given before a meeting of the British Interplanetary Society on 6 May, 1961.

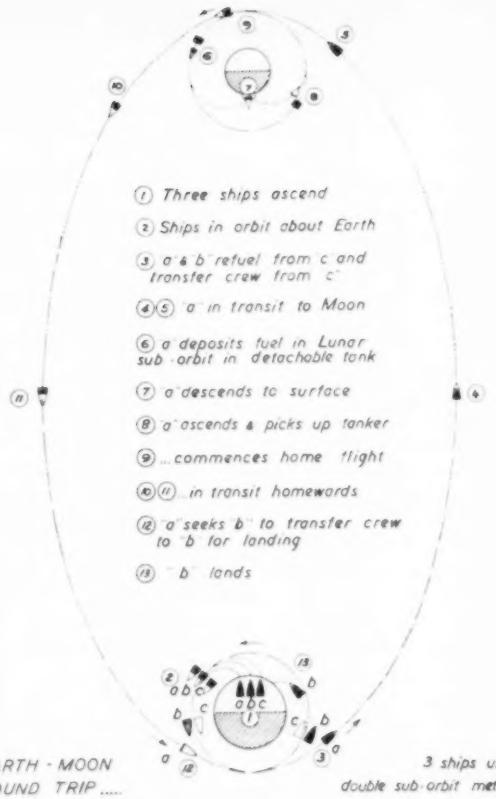
unable to do so, or were still hanging back timorously and with perhaps excessive regard to expediency. There were, within this period, no large official establishments—government agencies or industrial firms—which were very active in the field. Even those which were doing something of the sort were not able, or were not anxious, to publicize their activities. (I refer, of course, to the Western world; there must have been plenty of activity in the U.S.S.R., but of course this was even less publicized. It may even be that the B.I.S. exerted some small influence there, helping to steer Russian effort in rocketry towards astronautics; certainly the Soviet Republic from the earliest days was among the main subscribers to our journal.)

During all the post-war period, Len Carter has been the B.I.S. Secretary, and the Society could not have done a tenth of what it has without his efforts. Eric Burgess was the first post-war Chairman, for a year, followed by Arthur Clarke for another, then by myself for three years, and Clarke for another three. Les Shepherd then took over for three years; the late Ralph Smith for one, and Shepherd for another three, to be followed by Dr. Maxwell, our present President (the new title, revived from pre-war years, of our leading official). In the early post-war years, we maintained the pre-war post of Technical Director, and this was always filled by Les Shepherd. The list of post-war Councils has always included, for most of the period, such names as Gatland, Slater, Humphries, Thompson, Ross, Smith and several others to which I shall have cause to refer.

During this 1946–55 decade, when amateurs—the literal meaning of this word implies lovers of their subject—still had the chance to make major contributions, what did the B.I.S. actually do? Before we consider that in some detail, let me say that I firmly believe amateurs will *always* have a contribution to make. Only, that this opportunity is obviously less when highly-subsidised groups are also in the field. Also, that a vicious circle then begins to operate; the amateurs, with something like an inferiority complex, begin to believe that they cannot do much by comparison; this is not entirely true, and is a pity.

First, in the field of public education—propaganda, if you like—leading members of the B.I.S. gave perhaps over a thousand public lectures, on varying technical levels, but all presenting a reasonable, balanced, view of astronautics. They were also responsible for a great many similar radio and TV talks, and publications in book, magazine and newspaper media. John Humphries' Technical Abstracts, in the B.I.S. Journal, provided the best available single source of information on anything published on the subject.

On a different level of "education," the Society generated a number of presentations on the philosophy and "politics" of astronautics. Arthur Clarke's 1946 classic paper, "The Challenge of the Spaceship," is an outstanding example; it has been re-printed many times, all over the world. In it, he (still-optimistically!) predicted that a guided rocket would land on the Moon


(1) Three ships ascend
(2) Ships in orbit about Earth
(3) a & b refuel from c and transfer crew from c
(4)(5) a in transit to Moon
(6) a deposits fuel in Lunar sub-orbit in detachable tank
(7) a descends to surface
(8) a ascends & picks up tanker
(9) ...commences home flight
(10)(11) ...in transit homewards
(12) a seeks b to transfer crew to b for landing
(13) b lands
EARTH - MOON ROUND TRIP .....
3 ships using double sub-orbit method

This diagram, produced in 1948, exemplifies the technique of orbital re-fuelling as applied to a lunar-landing mission (H. E. Ross).

around 1950 (the Russian "Lunik" arrived in 1959), and that a lunar expedition would be achieved about 1970. It is only fair to mention that, in somewhat similar lectures of 1947 and 1953, I thought that satellite rockets might be developed by 1965 (cf. 1957 for the first two Sputniks!), and that manned orbital flights might be achieved in the 1980's (cf. Gagarin, in 1961). Nevertheless, I still expect to win (though I hope to lose) a £5 bet with Clarke that the first manned round-trip lunar expedition will not take place before 1970, though I would now bring forward my prediction for its date, of about 2000 A.D., into the 1970–1980 era.

In all these early discussions of ways and means, the B.I.S. did not neglect those matters of Space Law which often hit today's headlines, and another aspect of the subject to which the B.I.S. has always made a contribution, especially in the post-war years, has been the important question of International Collaboration. We have always thought that spaceflight, almost by definition, deserved a less parochial approach than that of the conventional, nationalistic attitudes and would, one day, even demand it. In all this discussion of the British Interplanetary Society's contribution, I am thinking not

so much of the essentially *British* aspect, as that of an active group which happens to have been substantially self-contained, and located largely (though not entirely) in the U.K., from which it was directed. Our foreign membership has always been high—around 25%.

In 1950, as a result of Franco-German initiative, the first Congress was held in Paris, with a view to forming the present International Astronautical Federation. The B.I.S. (which Cleator started in 1933) was then recognized as the natural leader of this movement; the A.R.S., though founded as the American Interplanetary Society in 1930, had since decided to be respectable, and played down its interest in spaceflight. Nevertheless, the A.R.S. was well represented at the second Congress in London in 1951, when the B.I.S. submitted its draft of the first I.A.F. Constitution, and the body was formally constituted.

The theme of the technical lectures at this 1951 I.A.F. Congress was the Earth Satellite Vehicle—which brings me to the subject which I was really asked to discuss—the *technical* contributions of the B.I.S. since the war.

During the 1946–55 decade, the B.I.S. undertook work on the following subjects; arranged lectures on them, and published the relevant papers in our Journals:—

Manned rockets, space-ships, space-stations, and space-suits: by Smith and Ross and others, whose main contribution might be said to be concerned with the emancipation of the subject from the purely science-fiction concept, of what Smithy liked to call the "space-going winged submarine, with rows of portholes" school of thought. In a similar vein, Clarke's suggestion of a "dumb-bell" shaped nuclear spaceship might be mentioned. Both were concerned with the design of space vehicles and equipment for their own very special environment.

Orbital rendezvous and refuelling techniques: by Ross and Gatland and others. The idea was not new, having been originated by von Pirquet and others in the 1930s, but it was vital, and it was elaborated. The idea of having specialised space-ships for different missions was developed.

Realistic project studies, on minimum satellite vehicles (taken up by Singer, in the MOUSE project), and on expendable tanks, etc., were made by Gatland, Kunesch, Dixon and others.

Highly-mathematical studies on optimum orbits and trajectories: notably by Derek Lawden, now a Professor in New Zealand. These papers are frequently cited as references in official reports.

The meteor danger: by Ovenden and Langton.

Radiation hazards: by Shepherd and others.

Interstellar flight: by Shepherd.

Nuclear and ion rockets: by Shepherd and myself—also by others, including several American authors who chose to publish their earlier papers in our Journal. Preston-Thomas, an English physicist who went to Canada, was another contributor in this field of advanced propulsion systems, also on orbit optimization.

Re-entry problems: by Nonweiler.

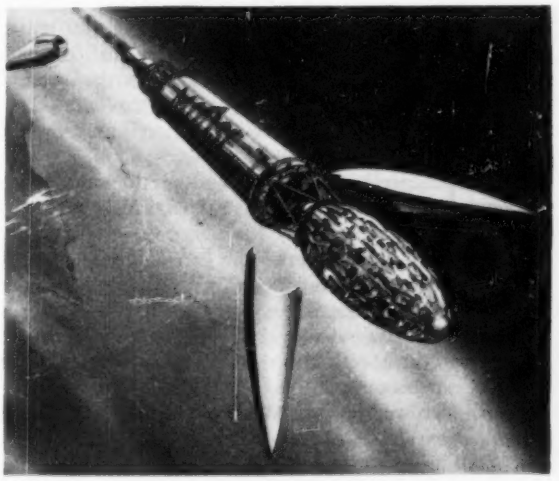
Mention of individual workers is invidious: the above list is far from exhaustive. There were also papers on space navigation, lunar bases, auxiliary power for spaceships and their cabin air conditioning and almost any other astronautical subject one could mention. Neat dealt with the limitations of the chemical rocket, Slater and others with space-medicine. Arthur Clarke held forth on many subjects, including electro-magnetic accelerators for launching payloads from the Lunar surface into orbit; he was also responsible for the first suggestion, to my knowledge, of the communications satellite—in *Wireless World* for October, 1945. Curiously enough, he never presented a paper on this important subject before the Society, but it was often mentioned in our public discussions, especially by Clarke.

We must not be, in the vernacular, "big-headed" about all these contributions. Many of them were not entirely original and other workers were studying many of the ideas concerned at the same time. Also, many of the best contributions on particular subjects were, at least in part, the work of overseas members: papers were published by Ackeret, Spitzer, Herrick and Bussard, among many others.

Nevertheless, during the period in question, of the first post-war decade, the fact remains that the B.I.S., as a whole, made a vital contribution to astronautics, of which we can justifiably be proud.

At the time, all the subjects in question were very novel, and not (in the view of orthodox science) entirely respectable. The part which we played was all the more significant; this has frequently been acknowledged to me personally, not least in the U.S.A.

During this time, of course, various leading members of the B.I.S. were engaged professionally in relevant



Last stage of a small satellite launching rocket, shown in the act of releasing an inflatable "metalized balloon" to facilitate optical and radar tracking from the ground. (After a suggestion contained in the 1951 paper "Minimum Satellite Vehicles," by Messrs. Gatland, Kunesch and Dixon).

J. W. Wood

fields, and therefore making some contribution beyond, as it were, their amateur status. Shepherd, for example, was with the Atomic Energy Authority; Neat and I in rocket engine firms; Smith and Humphries at R.P.E. Westcott, and so on.

It is interesting to note a few landmarks from the outside world during this 1946–55 decade. In 1947, the Bell X-1 rocket plane made the first supersonic flight; in 1949, a two-stage V-2/W.A.A.C. Corporal attained the record altitude of 242 miles; in 1951, a single-stage Viking reached 135 miles. Then, both the U.S.A. and the U.S.S.R. announced their intention of developing satellite rockets during the I.G.Y. This news was given out during the I.A.F. 1955 Congress at Copenhagen.

Perhaps it is really somewhat artificial to put milestones along the march of time, but one is tempted to say that 1955 was the beginning of a new era for rocketry and astronautics. At least in the West, it saw the commencement of intensive work on big rockets; on the I.R.B.M.'s and I.C.B.M.'s, and (from 1957 onwards) on the satellites and space probes. Even our own "Blue Streak" was begun in 1955!

The years since 1955, being closer, are more difficult to see in true perspective, as far as the B.I.S. is concerned. Inevitably, the character of the Society's contribution has tended to change. With a vastly greater amount of relevant work going on in official quarters—government establishments and industry—the Society has tended to become more of a forum, and a very good one, for the discussion and publication of this. Many amateurs have turned professional; others are deterred (often unnecessarily and unfortunately) from participating.

Another "deterrence," I suspect, has been the imbalance between the British (and indeed European) scale of effort on rocketry, and that in the U.S.A. There is a regrettable tendency for much of our Journal to be filled by American papers; it is not that one regrets the number of these—rather, that we do not produce more of our own, though the reasons are not difficult to seek.

During the most recent five or six years, indeed, the major contribution of the B.I.S. has undoubtedly been its campaign on behalf of a British—or better still, an Anglo-European—space programme. Without this, it is difficult to visualise more than a spectator or reporting future role for our Society. With it, we may go forward to play a continuing significant part in the future of astronautics, worthy of our past traditions.

Russia's Space Plans

The next steps in the study of the Moon will evidently be the establishment of artificial satellites of that planet maintaining radio and television communications with the Earth, the soft landing of rockets with scientific instruments on the Moon, the automatic take-off of rockets from the Moon to return to Earth and, finally, manned flights to the Moon.

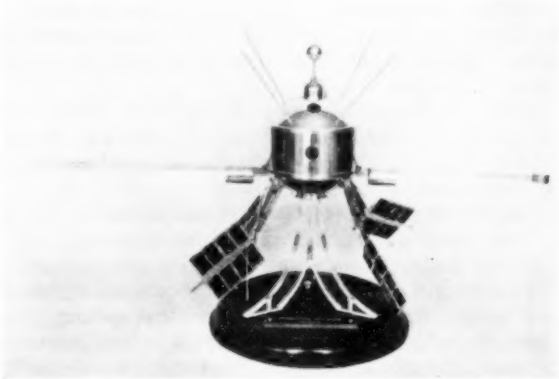
These prospects are discussed in the newspaper *Ekonomicheskaya Gazeta* by Nikolai Varvarov, an authority on astronautics.

"It is now quite obvious that artificial satellites are extremely necessary for the study of other celestial bodies, apart from the Earth," he says.

Varvarov points out that the information provided by the study of the Moon with the help of artificial satellites will still not be quite exact. Therefore the need arises for the delivery to the Moon of special automatic stations provided with the necessary equipment. To carry out observations in various parts of the lunar surface, these stations must be made mobile and remote-controlled.

Discussing prospects for manned flight to the Moon and return to Earth, Varvarov points out that the initial weight of the rocket must be 300 times greater than the final. This is impossible at the present stage of the development of rocketry.

Manned flight to the Moon, he says, will be preceded by a manned flight round the Moon with a return to Earth. To ensure the success of such a flight, it is necessary to establish artificial satellites of the Earth capable of refuelling Moon-bound rockets.



Scale model of the S-51 satellite which N.A.S.A. is providing for launching some 25 lb. of British instrumentation early next year.
United States Information Services.

From Airlines to Spacelines

By Capt. R. C. TRUAX, U.S.N. (Ret.)*

We are pleased to include this article by a pioneer of American astronautics. The author built and tested a regeneratively-cooled liquid rocket motor while a Midshipman in the U.S. Navy in 1936–39. *A Past President of the American Rocket Society, he received a Navy Legion of Merit Award for work on Polaris, and in* 1951 *was presented with the Robert H. Goddard Medal for outstanding contributions to rocketry.*

"Mankind is about to populate the Universe. Within 50 years there will be permanent colonies on our Moon, Mercury, Venus, Mars and perhaps on the moons of Jupiter and Saturn. Numerous manned artificial satellites or planets will have been placed in the solar system, and the interplanetary spaces will be filled with spaceships making routine, scheduled trips from planet to planet."

Today one may make a prediction such as this and have it printed in a reputable magazine, or announce it in a public forum, without having his sanity questioned or his integrity impugned. The public has become so accustomed to spectacular advances in science and technology that it has become well nigh impossible to make a prediction wild enough to elicit a sceptical outcry. In the field of astronautics in particular, no claim is so fantastic as not to be given credence.

What a change from the early days of science, when new findings which contradicted "common sense" or the established doctrines of the day were ridiculed and their discoverers scorned—or even persecuted! It is said that the principal Professor of Philosophy at the University of Padua refused to look through the telescope of Galileo to see with his own eyes the evidence on which the latter claimed the existence of craters on the Moon.

Historically, the pessimists have nearly always been wrong. Apparently even our wildest dreamers have underestimated the actual rate of technological progress. The sceptics and disbelievers have become discouraged, so seldom have they been able to say, "I told you so."

Perhaps, however, a sceptical element is needed now, if only to prod us into a critical examination of our accomplishments of today and predictions for tomorrow.

The conservative prediction is usually based on current knowledge and present ways of doing things. If we had alive today a tough-minded sceptic, still not shell-shocked by the happenings of the past, the prediction of the opening paragraph could be examined in the light of *current* techniques and made to look very foolish indeed.

Rocketry, it might be pointed out, is a very expensive art. Compared with prior forms of locomotion, a rocket, particularly a space rocket, is a huge, highly engineered vehicle which carries a minuscule payload. Moreover, these enormous machines make one roaring flight of only a few minutes duration and then crash as a mass of twisted or molten wreckage. Examine the overall cost data for project Vanguard. Here a vehicle costing in the neighbourhood of 2 million dollars was used to put about 20 lb. into a satellite orbit. The cost of transportation, based on vehicle cost alone, is $100,000 per lb. The total programme succeeded in putting about 125 lb. in orbit at a cost of some $125,000,000—or a million dollars per lb. Certainly on a large scale, such operations would exceed in cost the entire gross national product, and the idea of spaceships plying between the solar bodies on a routine basis is far fetched indeed. It might well be contended that the astronautic rocket is an expensive toy of the scientist, incapable of growth into a means for transporting people and goods of an everyday nature.

Yet the prediction made in the initial paragraph *is* the author's—the negative arguments are only an attempt to analyse why pessimistic extrapolations are usually wrong.

The time is not far past when the author and others of similar bent were scratching their heads and their pencils very hard to show that *any* payload *whatsoever*, at any cost, could be placed in an orbit around the Earth. This most elementary of all space missions seemed on the borderline of practical attainability.

As recently as 1948, the Research and Development Board of the U.S. Department of Defence concluded that creating an artificial satellite was marginally feasible, but that the "foreseeable military utility does not justify the cost." As a result of this decision, a project then in existence directed toward creating the world's first artificial satellite was cancelled. (Here, incidentally, is where the United States relinquished to the U.S.S.R. its chance for leadership in space.)

How close we were to the edge of the impossible was demonstrated by Vanguard I, when a 3-lb. satellite (Kruschev's grapefruit) had to be substituted for the original 20-lb. to save 17 lb. of weight. Seventeen lb.—out of a gross take off weight of some 22,000 lb.—meant the difference between success and failure. Yet now, without any obvious major advances in technique, payloads in excess of a ton can be placed in orbit.

The primary reason for the improvement, and the reason which can lead one to be optimistic about the future, is that we continuously find means for improving the performance of our equipment on a *cost* basis, as well as improving it on an *engineering* basis. Over the past 10 years, the improvement in items critical to the performance of a rocket, such as propellent consumption and structural weight, has not been decisive. The principal change has been an increase in size, and a

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reduction in unit cost because of an expanding utility which permits one-time costs to be spread over a larger number of units. This is a self-propagating procedure which leads to explosive growth. An increase in utility spreads out the cost, which in turn opens new spheres of application and the cycle begins anew.

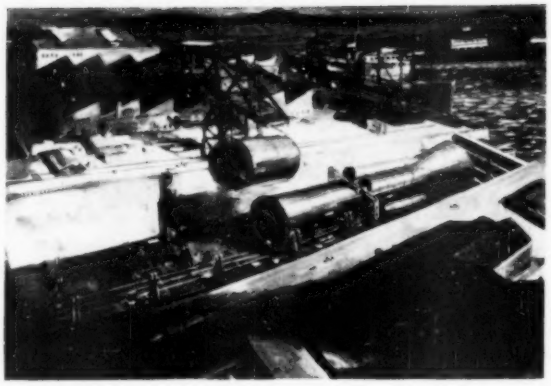
An increase in missile size has two important effects. The first is that the proportion of useful load which may be carried increases. This increase results from the fact that many of the items of equipment which must be carried for a vehicle to fulfil its mission are of fixed size and weight, regardless of the size vehicle to which they are attached. The guidance equipment is a notable example. In addition, there are certain practical limits to the thicknesses of the metal which may be used, imposed by limitations in fabricating techniques. As a result, large structures can generally be made somewhat more efficient than smaller ones.

In addition to these purely engineering advantages, there is a cost advantage as well. In general, for a given degree of complexity, it costs no more to design a large structure than it does to design a small one. Nor does it usually require a proportionate increase in the testing cost. In the manufacturing phases, the cost increase is not usually in direct proportion to the weight. Very frequently although larger machines must be used in the fabrication process, and hence a larger capital investment is necessary, the labour costs do not go up in proportion. For example, it normally requires one man to attend a lathe, whether this lathe be a large one or a small one.

It is not difficult to find examples where the size-cost relationship is extremely flat or even negative. Two liquid rocket engines in our current stable are quite similar in design and construction. They differ by a factor of about 10 in thrust and differ only 10% in cost. Two current *vehicles* of very similar design differ also by a factor of 10 in weight, yet the smaller costs nearly twice as much as the larger. The point is not that it costs less to make larger vehicles of the same design, but that differences other than size, such as comparatively unnoticeable differences in complexity, differences in production quantities, etc., can overshadow even very great differences in size.

Similarly, when reaching the flight testing or operational phase of a space vehicle programme, there are many factors which do not vary with the size of the vehicle, or which vary in less than a direct proportion. In general, the time and manpower required to conduct pre-flight checks is a function of the complexity of the missile, rather than of its size. In erecting and servicing a vehicle, somewhat larger equipment will be required, but usually the increase in manpower will be small.

After a vehicle is launched, many of the functions still to be performed do not vary at all with size. These functions consist primarily of tracking and communications. Certainly it requires no more expensive an operation to track a large missile than it does to track a small one. In fact, cheaper and simpler equipment may sometimes be used for the large missile.



Construction of the three-stage "Skyliner" booster takes place in drydock facilities.

All pictures Aerojet-General Corporation.

The above are all *qualitative* factors which tend to justify and explain the past history of increasing size for space vehicles. That history has been so short, however, that the end point cannot be readily perceived. It is interesting to note that the trend toward an increase in size of ships has continued over hundreds, even thousands, of years. The first 50 years of flight have seen a constant increase in the "maximum size" of aircraft. A severe restraint on the size of surface ships was placed by the dimensions of the locks of the Panama Canal. In spite of this restraint, the economic and other factors favouring extremely large vessels has led to the construction of ships too large to negotiate the canal. For some time, the size and strength of airport runways has tended to limit the size of aircraft operating from them. The superior economics of large aircraft nonetheless have justified a larger investment to provide larger and more adequate airport facilities.

It may be argued that the difficulty of transporting a very large space vehicle from its point of manufacture to its launch site may constitute a major deterrent to the construction and use of really large space vehicles. The current Saturn vehicle is already too large to be transported either by air or by land. It is perfectly possible, though, to transport the Saturn by barge from Huntsville, Alabama, to Cape Canaveral.

In fact, rockets will float, and there seems to be no reason why they cannot be assembled in a dry-dock, like a ship, towed to the point of intended launch, serviced in the water, and launched from a floating position, without the requirement for launch structures of any kind. Such launch techniques are now being explored by the Naval Missile Centre at Pt. Mugu, Calif., where boiler plate models are being launched directly out of the water.

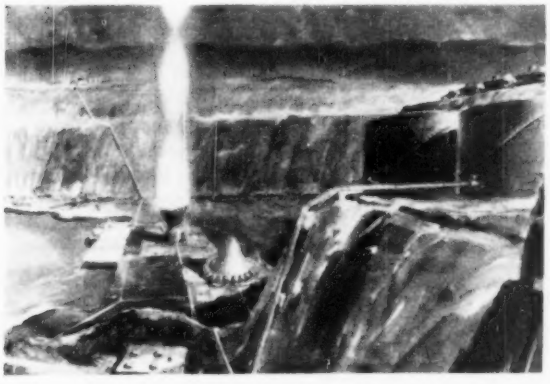
With such an operating concept, rockets in excess of 100,000,000 lb. weight could be handled.

The development of such large rockets means the size and cost of static testing facilities becomes formidable. Several innovations, however, could bring costs of both facilities and developmental tests to a reasonable level. Rocket engines could be tested nozzle up instead of nozzle down thus eliminating the huge flame deflectors and water supplies currently required and replacing the massive holddown structures with simple concrete pads.

Water access to the test area would be required to permit transportation of the huge thrust chambers, which might be as large as 150 ft. in diameter and 150 ft. long.

The above arguments indicate that an increase in vehicle size may make a major contribution to reducing the cost, hence improving the utility of space operations. The possibility and potential in this direction should be carefully explored from an economic as well as an engineering point of view.

In an attempt to find additional means for reducing the cost of the space programme, one cannot fail to note that in no other mode of transporation does one even contemplate expenditure of the vehicle after only one trip. Such a procedure for aircraft, train, automobile or ship transportation would impose an economic penalty that would completely erase the commercial utility of the system in question. The science of space transportation is historically related to the guided missile. In such use, the vehicle is either automatically destroyed at the end of the flight, or is used under such circumstances as to render recovery of the vehicle extremely difficult. It is true that space vehicles are in general of relatively fragile construction and that they reach velocities and altitudes incomparably greater than those attained by any other vehicle. Nevertheless, if we examine the technical problems of providing a multiple use capability, these difficulties do not seem insurmountable. In the case of the first stage of multi-stage rockets, which because of their size represent a major fraction of the total investment, recovery and re-use seem relatively simple.

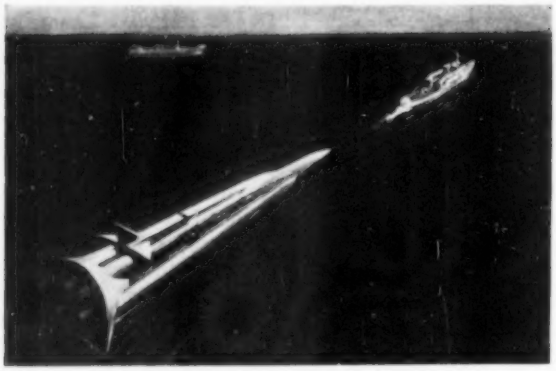


Testing can be accomplished with the nozzle up, eliminating the huge flame deflectors and water supplies needed in present test rigs.

Since the velocities acquired by succeeding stages are progressively greater, the difficulties associated with their recovery and re-use also increase. In all cases, however, the loss of payload which results from the incorporation of recovery provisions can be offset by the economic gain associated with re-use of the vehicle, provided that the re-use factor is sufficiently high. Current indications are that the number of flights required to effect this amortization of recovery provisions is far below that associated with normal aircraft operations, for example. Since final stages frequently contain complex payload equipment, a disproportionate share of the total cost is contained in these final stages. As an intermediate phase in the development of completely recoverable vehicles, we may find that three-stage combinations in which first and last stages are recoverable and the intermediate stage expendable may find wide utility. In such a case, of course, the intermediate stage should be made as inexpensive as is consistent with reasonably good performance.

There is, throughout the industry, a gradual awakening of interest in recoverability. In most studies made to date on the economic recovery associated with the physical recovery, it appears that the missileman's point of view has dominated the thinking. In some cases it has been assumed that the missile would have to be entirely rebuilt; that is, returned to the factory, completely disassembled, defective or damaged parts replaced, reinspected, retested and shipped again to the launching site. The cost saving associated with such a procedure is naturally relatively small. It is, of course, a far cry from normal aircraft operating technique. As a general rule, between aeroplane flights only an insignificant fraction of initial vehicle cost is expended in servicing and pre-flight checks. Increasingly extensive maintenance is conducted at intervals in the order of 30 hr., 150 hr., 500 hr., etc. Whether rocket vehicles will ever attain maintenance schedules comparable on a time basis with these may be open to question, yet there is sufficient similarity of a general nature between aircraft and rocket structures to make it unwise to disallow such a possibility.

A rocket vehicle designed to be re-usable may differ markedly from an expendable one, or the differences may be in detail only. Depending on the manner in which recovery is to be effected, a booster vehicle may have wings and auxiliary air-breathing power plants, and may be very much more like an aeroplane than a rocket, or it may be designed very much as it has been in the past, and equipped only with parachutes, braking rockets, or other auxiliary devices to increase the probability of successful recovery. Because of the large financial investments associated with aeroplane type recovery systems, it appears probable that the simpler methods of booster recovery will be investigated first. In considering the recovery of first stages by parachutes and retro-rockets, it would appear that a booster designed to be recoverable would place rather heavy emphasis on simplicity and reliability, at the expense

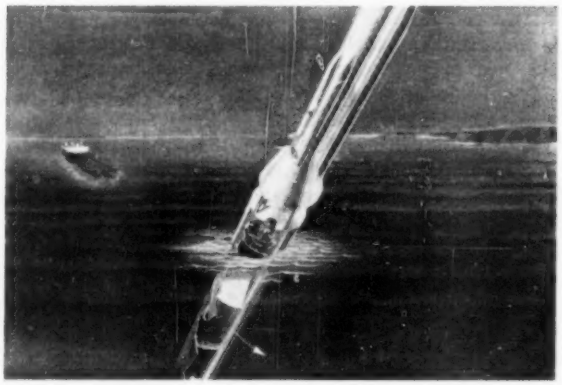


The Completed "Spaceliner" is towed from the drydock to the sea launch area.

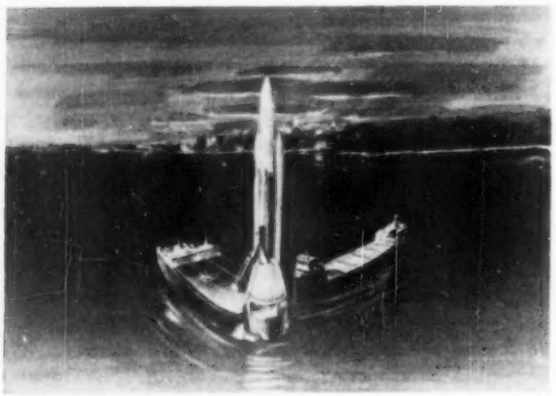
of performance, if necessary, since it appears probable that the total number of flights attainable would be a direct function of the reliability. It also seems likely that the reconditioning and check-out cost would vary in proportion to the complexity.

Even granting the development of very large recoverable vehicles, it may still be difficult to visualize space operations being routinely conducted on a large tonnage basis. The rocket vehicle appears to be such an enormous thing for the amount of payload carried. It should be noted, however, that 80 to 90% of the total mass of the rocket is propellent which, at least in the case of conventional liquid-fuel rockets, is very cheap indeed. Liquid oxygen and kerosene, such as used in our Atlas and Titan missiles, are available in unlimited supply, at a cost which is in the neighbourhood of 2 cents a pound. Even with our present relatively inefficient vehicles, the propellent cost per pound of payload put into orbit, for example, is less than 2 dollars. Were this the only factor, beefsteak could be obtained at our satellite commissaries for less than three times the price at a terrestrial supermarket, a quite modest increase under the circumstances.

To summarize, spaceflight is due for an explosive expansion over the next 50 years. The increase in activity will result from two main factors; first, an increase in utility which will justify a several-fold increase in financial support. Secondly, there will be a decrease in the cost of space operations which will permit more



The "Spaceliner" is erected into the firing position by allowing sea water to flow into a section of the launching pontoon.



The passenger tender is floated into position, providing for preflight preparations and boarding of passengers, who arrive by helicopter.

flights to be made for the same number of dollars. The decrease in cost-per-ton mission in turn will stem primarily from two factors. The first of these is an increase in vehicle size which will give increased payload without a proportionate increase in cost. The second major cost reducing factor will be an alteration of concept, abandoning the use of one-shot vehicles and going to those which are suitable for hundreds--or even thousands—of flights in the course of their normal lifetimes. This ascending spiral of utility and economy will make possible the support of hundreds of people at extra-terrestrial locations in the foreseeable future.

Design, development, fabrication, and operation of these true spaceships will be a large and very expanding industry.

Possible Operations on the Moon

By DR. FRITZ ZWICKY*

On our march into the Universe, the Moon is a natural first stage, which will be followed by journeys to to the various planets and their moons. The main purpose of these journeys will be the exploration and, later on, the reconstruction of as many members of the solar system as possible for the purpose of making them habitable.

The Moon appears to be a most inhospitable place because of its extreme heat and cold, its exposure to dangerous types of solar and cosmic radiation, and its lack of a life-sustaining atmosphere. A closer look, however, reveals that conditions on the Moon are much better than they appear at first sight. From our knowledge of the composition of the Earth, the Sun, the planets, meteors, and comets, we may assume with confidence that all of the essential chemical elements will be found on the Moon. With some imagination and determination toward the development of a few rather simple devices, it should be possible to make the Moon readily habitable and actually quite an exciting place to live.

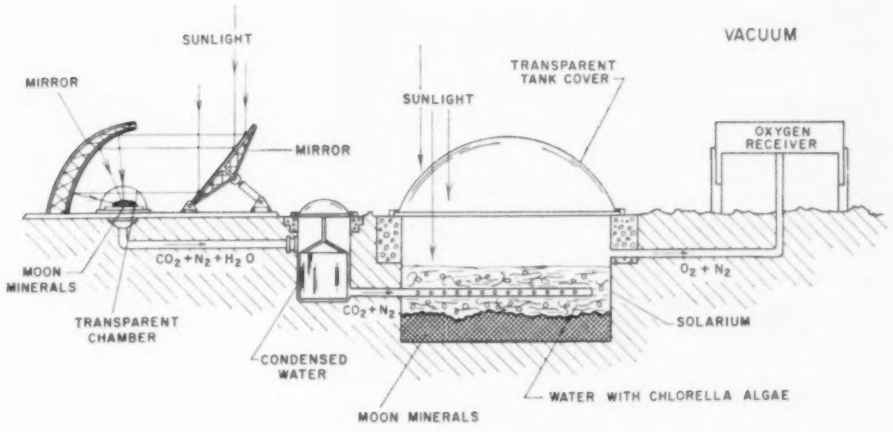
The seemingly adverse conditions on the Moon actually in many ways facilitate the operation of devices for the production of oxygen, water, and food, as well as fuels and propellents for conventional power plants and for rockets. For example, the absence of an atmosphere on the Moon is, curiously enough, one of the most valuable means for processing essential materials into things which we use in everyday life. Metals—aluminium and some of its alloys—can be produced with a purity and a "specificity" of properties in this perfect vacuum that are not attainable in the highest artificial vacuums in our laboratories. Such metals can, for instance, be welded by simply hammering them together. Indeed, as my colleague Professor Pol Duwez has pointed out, no oxides will be formed on our metals which, in the Earth's atmosphere, must be hot-welded or riveted.

In the full glare of the Sun, the lunar surface temperature rises above that of boiling water. During the lunar night, it sinks to 250° F. below zero. Visitors to the Moon must dig in or construct shelters immediately upon their arrival in order to protect themselves against temperature extremes as well as against the dangerous particle radiations which are sporadically being ejected from the Sun. With the aid of solar furnaces as shown in the accompanying sketch, the dust, sand, or gravel on the Moon's surface can readily be melted and cast into bricks. Also, available rocks may be hot-welded to build walls for shelters.

Construction on the Moon will be easier than on the Earth because all materials weigh one-sixth as much. This is because of the lighter pull of gravity. One man can handle huge beams, plates, and blocks for construction.

The visitor's next concern will be to produce breathable atmosphere in the shelters and to produce water and foodstuffs from the Moon's surface materials. For

* *Professor of Astrophysics, California Institute of Technology and Chief Research Consultant, Aerojet-General Corporation.*



Solar furnace and related equipment for the production of water, oxygen, nitrogen and food on the Moon.

these purposes, the simplest and most readily available power source is the radiation from the Sun which can be concentrated with solar furnaces. A number of these devices, similar to the type shown in the sketch, can be used to produce water, oxygen, nitrogen, foodstuffs, propellents, and power. The furnaces consist of flat and concave mirrors which follow the course of the Sun and continually focus radiation on to a spot on the Moon's surface, which is tightly covered by a transparent bell jar.

Water can be obtained first. The igneous rocks in the Earth's crust contain from 1 to 10% of water of crystallization. Similar percentages may be expected on the Moon, at least in shallow, subsurface layers. This water will be driven out of the rocks as they are exposed to the intense heat—over 5400° F.—in the focal spots of the solar furnaces. The water vapour steaming out of the rocks can be used to drive turbines and thus produce power before being condensed into water for drinking purposes. The steam can also be condensed directly or be used for assimilation in a closed plant garden.

Carbon dioxide is the next gas to be liberated from the rocks in the hot focal spot of a solar furnace. Calcium carbonate will be dissociated into carbon dioxide and calcium oxide, and the carbon dioxide may subsequently be fed through a covered garden for digestion in chlorella algae and the like. It may be dissociated into oxygen, carbon, and carbon monoxide in a second, more efficient solar furnace that is capable of generating temperatures of 7000 to 8000° F. For these processes, the use of plants will, of course, be far more efficient for long-term operations. Large gardens, covered with a transparent material, can easily be constructed which make direct and efficient use of sunlight. This will eliminate the necessity of too many or too large solar furnaces. In addition, the chlorella algae, with the aid of sunlight, produce food rapidly through their ability to synthesize starches and proteins from carbon dioxide, water, sulphur, nitrogen, and phosphorus, which we can make available in our Moon garden.

A solar furnace of 1 sq. yd. aperture collects and concentrates enough energy to generate 70 gal. of oxygen per hour at atmospheric pressure from the dissociation of carbon dioxide, from water, or from any of the metal oxides available. This is enough for more than fifteen people, at the breathing rate of about 4 gal. per person per hour. On the other hand, a larger solar furnace is needed to produce water. Unless the visitors to the Moon are lucky and find rocks in which the water of crystallization is very loosely bound, they will need a solar furnace the size of the 200-in. mirror of the great Hale telescope on Palomar Mountain to produce a lavish 6 gal. of water a day. Or, if they can be satisfied with a daily 6 qt., they can get this from a mirror the size and the quality of familar 60-in. searchlights.

The visitor can use two methods to produce power. He may first produce propellents—hot steam is the simplest—followed by hydrogen and oxygen which he gets from the thermal dissociation of water; or he may produce metals, carbon, and silicon from the dissociation of their oxides. These elements may subsequently be reacted with either oxygen or hydrogen in combustion chambers which are designed for the operation of gas turbines or, if need be, of jet engines and rockets. The astronaut may also use a very efficient solar furnace which produces temperatures high enough not only to dissociate the rocks on the Moon down to their chemical elements, but to ionize most of the latter. In a properly designed focal reaction chamber built, for instance, from some carbide with a very high melting point, jets of electrically charged positive and negative ions can be produced and shot through the space between the poles of a magnet. From electrodes placed on both sides of the jet parallel to it and to the magnetic field, an electric current can be drawn off this "jet induction generator."

Oxygen, water, food, propellents, and energy stored in batteries must be produced in excess quantity during the lunar day for purposes of storage and use during the lunar night, each about 2 weeks long. Also, the shelter and the food-raising gardens must be protected against the intense cold.

The equipment which, say, three visitors must take along for their first trip to the Moon is extensive. Parts for the flat and concave mirrors of solar furnaces with a combined aperture of perhaps 100 sq. yd.; supports for the furnaces; plastic bell jars; high-temperature crucibles; pipes and jars for traps; small magnets; wires; aluminium tubing; simple tools of Dural or titanium alloys; some auxiliary devices like pumps and solar batteries; and some salts, vitamins, medicines, sun lotions, and the like. All in all, the three should get along on 1000 lb. of equipment.

Summarizing, we must emphasize that none of the operations described in the preceding goes beyond scientific and technological knowledge that is already at hand. Even larger vistas will open once we master the nuclear fusion ignitions of all of the lighter chemical elements in the rocks and can transform them with tremendous release of energy into the heavier elements—iron is the ultimate goal. Most of the research on the ignition of nuclear fusion at the present time is concerned with electromagnetic means which might produce the necessary conditions for the desired nuclear reactions to take place within clouds or plasmas of electrically charged positive and negative ions. Personally, I am of the opinion that quite different and more promising methods of nuclear fusion ignition are possible.

Once nuclear fusion of the elements in the rocks is mastered, the following operations become possible on the Moon: First, the lunar night can then be made very comfortable. Second, with the large energies available from nuclear fusion reactions, we might visualize endowing the Moon with an atmosphere of heavy molecules—carbon dioxide, for example—which are heavy enough not to be swept off the Moon in spite of its slight pull of gravity. And finally, with the aid of

nuclear fusion, we can literally "move mountains," or even shrink the size of the Moon and thus increase its pull of gravity for the purpose of allowing it to hold a breathable atmosphere like our own.

It must be emphasized that the projects I have outlined can be realized with the aid of present-day knowledge and techniques. A few shots at the Moon with small projectiles and spectroscopic observation of their impact using the 200-in. telescope on Palomar would give us much valuable information about the mineral composition on the Moon's surface. I have advocated the launching of fast pellets from rocket-borne, shaped, explosive charges for the past 15 years. A first attempt, on 17 December, 1946, with a V-2 rocket at White Sands Proving Grounds, failed. After much delay, Mr. J. Cuneo and I succeeded in launching a small pellet from an Aerobee rocket. The Aerobee was fired from Holloman Air Force Base and the small pellet—which was fired at a speed of 50,000 ft./sec.—actually became the first man-made body to escape permanently from the Earth. The pellet is now orbiting the Sun in interplanetary space.

No intrinsic difficulties face us that are of the magnitude of those which must be overcome by the investigators into the fundamental laws of physics, biology, and medicine. Imagination and an indomitable spirit are all that are needed for success in this project.

Canadian Sounding Rockets

A joint Canadian Government/Canadian Industry programme is actively developing a family of three solid propellent rockets for space research. The rockets will be capable of carrying scientific instruments of from 25 to 250 lb. to altitudes of from 100 to 600 miles into space. The rockets are as follows:—

Black Brant III—Single-stage, 10 in. diameter.

Black Brant IV—Two-stage, 17 in. diameter—1st stage, 10 in. diameter—second stage.

Black Brant V—Single-stage, 17 in. diameter.

A joint team made up of the Department of Defence Production, Defence Research Board, and Bristol Aero-Industries Limited, is responsible for the development programme. The Armament Branch of the Department of Defence Production is the Project Manager for the programme and provides overall control. The Canadian Armament Research and Development Establishment of the Defence Research Board is the design authority and is performing the solid propellent development required. Bristol Aero-Industries Limited, Winnipeg Division, is the prime contractor and is carrying out the vehicle design and development. Others assisting in the design and development programme are the Defence Research Telecommunications Establishment of the Defence Research Board, and the National Research Council.

The rockets will utilize Canadian solid propellents developed at Carde and will take advantage of the experience at Carde in developing the Black Brant I and Black Brant II rockets. Bristol Aero-Industries Limited has been doing design work on the rockets as a private venture over the past 2 years, and proposed the development of the rockets to the Government. The proposal was accepted and the contract was placed with Bristol Aero-Industries Limited to produce the rockets. Prototypes will be launched at the Fort Churchill Rocket Range in 1962.

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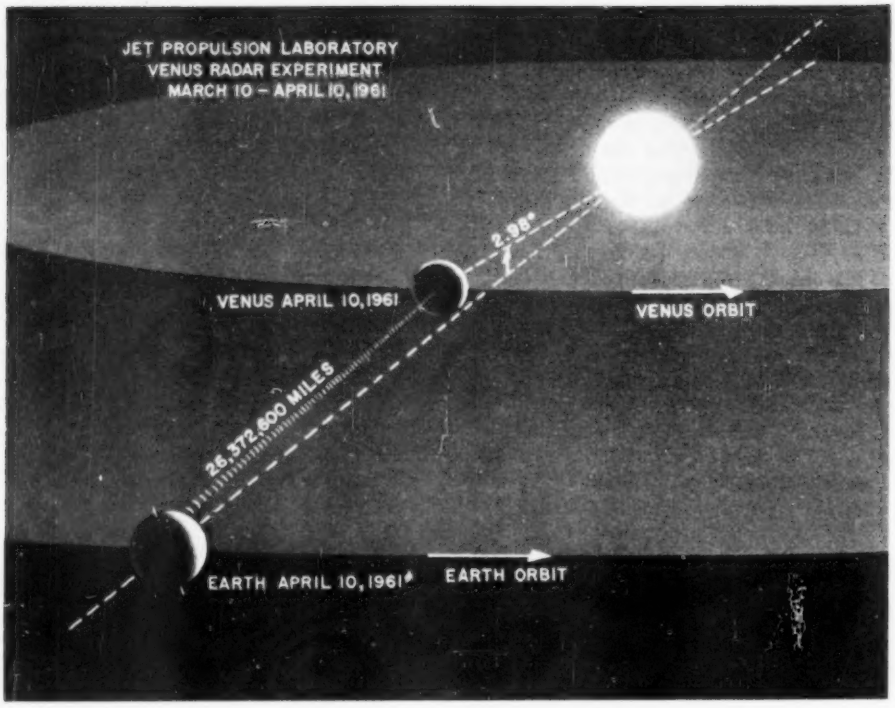

Exploring Venus by Radar

Earlier this year, important experiments were performed both by the Nuffield Radio Astronomy Laboratory, Jodrell Bank, and the Jet Propulsion Laboratory in America, to determine a value for the Astronomical Unit with greater accuracy. This article deals with the work accomplished in the United States.

A two-month Venus "radar bounce" experiment, conducted for N.A.S.A. by the Jet Propulsion Laboratory, is believed to have produced, among other interesting results, a more accurate yardstick for measuring distances in the Universe. Preliminary results give a value of the Astronomical Unit—the mean distance between the Sun and the Earth—as 92,956,000 statute miles, plus or minus 1000 miles.

In addition, the experiment produced data which indicated that Venus rotates at an extremely slow rate, perhaps as slow as once per 225 days, which is the length of the Venusian year as it rotates around the Sun.

The results were announced by Walter K. Victor, communications system research section chief, and Robertson Stevens, communications elements research section chief, co-directors of the Venus radar experiment. They added that refinement of the data is expected to reduce the uncertainty of the AU to plus or minus 100 miles.

Using its Goldstone Deep Space Instrumentation Facility 50 miles north of Barstow in the California Mohave Desert, JPL was successful in making radio contact with Venus at 2388 Mc./s. daily from 10 March to 10 May.

A signal was radiated by the Goldstone 85 ft.-diameter transmitting antenna to intercept Venus. The reflected echo was picked up by the 85 ft.-diameter receiving antenna at Goldstone.

The four principal objectives of the experiment were to: Refine the Astronomical Unit (AU) to a greater accuracy than the present uncertainty of 60,000 miles; determine whether Venus spins on its axis and the rotation speed; determine the orientation of the Venusian spin axis; investigate the nature of the surface of Venus as determined by the reflectivity of the surface.

"The most important goal of the experiment, the refinement of the AU, has been met," said Victor, "and analysis and refinement of the data will produce definitive answers to the other questions."

Dr. Eberhardt Rechtin, J.P.L.'s Programme Director for the Deep Space Instrumentation Facility, said data obtained in the experiment will be of great value in the programme to send instrumented spacecraft to Venus and the planets.

"Until now," he said, "we have not known the position of the planets to any great accuracy because of the uncertainty in the A.U. Clearly, this lack of knowledge of the position of any planet at any time would increase the engineering difficulty in an attempt to impact Venus or Mars or to place a spacecraft in orbit around one of the planets.

"Another uncertainty, the unknown reflection properties of the surface of Venus, previously made design of spacecraft radars almost impossible. This uncertainty now has been removed. A determination of the slow rotation rate of Venus also reduces the uncertainty of landing on the surface."

The AU is arrived at by using angular parallax measurements, or by measuring angles, and then projecting the angle measurements into miles.

The angular measurements themselves are extremely precise, but in converting them into distances between the Sun and the Earth in the form of miles, one necessarily runs into small errors.

Thus, 50 years ago, the AU plotted by classical astronomical methods, had an uncertainty of 250,000 miles. New approaches in solving the problem, however, have resulted in a considerable reduction in this error.

Before the introduction of radar astronomy technique, it was felt that the AU was known to within 60,000 miles. While this accuracy nominally is satisfactory for classical astronomy, it clearly is a serious handicap to a planetary exploration programme.

Perfection of radar astronomy techniques, based on the known velocity of light—approximately 186,000 miles/sec.—made it possible then to directly measure distances and velocity in terms of miles.

Thus a transit time is measured for a round trip of a radio signal between the Earth and Venus. This value, used in conjunction with the angular measurements made by earlier investigations, makes it possible to determine the mean distance between the Sun and the Earth.

Venus is the next closest planet to the Sun from the Earth. Because of its similarity in size to the Earth and its relative closeness, it long has been a source of interest to astronomers. Attempts to observe the planet have been hampered, however, by the dense clouds that continually hide Venus from observation.

Spectrographic studies—involving the breakdown of light rays into components of the spectrum and the analysis of the components—seem to indicate slight traces of water vapour, probably no free oxygen, and strong concentrations of carbon dioxide.

Venus orbits the Sun once every 225 days in comparison to the Earth's orbit of 365 days around the Sun. This means that Venus and the Earth approach closest to each other once every 19 months, a period which is called inferior conjunction. At this time, which occurred on 10 April this year, the distance between the two planets was 26·3 million miles. Maximum separation of Earth and Venus is 162 million miles.

Present development of radio communication makes it impractical to attempt radio contact with Venus except for comparatively brief periods before and after inferior conjunction.

The target date for the beginning of the experiment was 14 March, but operations actually began 4 days earlier as a result of what was to have been a practice run.

On 10 March, the observers took their places at the Goldstone controls for a simulated test, including a scaled down test using the Moon—some 250,000 miles away—as a target.

Transmitter power was turned down so that the signal sent out to the Moon and reflected back to the Goldstone receiver approximated the signal expected from the more distant Venus, then some 35 million miles away.

In the Moon test, about one-tenth of the power used to light an ordinary flash light bulb was transmitted to the Moon, to be reflected back to the receiver. This is analogous to directing an ordinary household flashlight at an object 250,000 miles away and getting a reflection.

This Moon test worked so well, and the equipment checked out with such precision on the simulated test of 10 March, that the decision was made to start the Venus experiment that day, rather than wait until 14 March.

Thus, at approximately 6.27.30 p.m. (P.S.T.) 10 March, the transmitter and receiver antennas at Goldstone were aimed at Venus, using optical television systems that allowed the operator to position the big antennas on Venus by means of a television camera mounted on each dish.

This signal, travelling at 186,000 miles/sec., took 3¼ min. to traverse the 35 million miles between the Earth and Venus, and another 3¼ min. to return to the Goldstone receiver. Thus, the round trip of 70 million miles took a total of 6½ min., and was completed at 6·34 p.m.

The Goldstone receiver used both a maser and parametric amplifier. Heart of the maser amplifier was a ruby crystal, which was maintained at the temperature of liquid helium (452° F., a few degrees above absolute zero) in order to reduce the receiver-generated noise power to a small quantity.

If one aimed a radio signal at a perfectly conducting sphere, one could expect 100% of the signal to return in the form of an echo. Using this as a standard of conductivity, the radio returns from Venus indicate that it has a reflectivity of 12%. This number is similar

to the value of the reflectivity of the Earth. Similar experiments on the Moon show the lunar surface has a much lower reflectivity of about 2%.

Polarization studies of the radar returns at Goldstone further indicate that Venus scatters the Goldstone signal at 2388 Mc./s. in a manner quite similar to the Moon, probably indicating that Venus has roughness characteristics at a scale of feet similar to the lunar surface.

A radar signal will be spread in frequency on return if the target planet is rotating and is rough enough to send returns from a considerable area on the surface. The accurately measured frequency spread of the Goldstone Venus echo (5 to 10 c./sec.) would then suggest that the rotation rate of Venus is extremely slow, probably as slow as once per Venusian year—225 Earth days. This estimate of slow rotation rate is in agreement with certain astronomical measurements.

Victor explained that the final results are dependent on calculation of the orientation of the spin axis of Venus, a difficult calculation for such a slowly rotating body.

Astronautics in School*

A Pilot Scheme in the United Kingdom

By A. J. MOORE,† B.Sc.

Curriculum change in education in the United Kingdom is notoriously difficult to bring about, not only because of administrative problems but also through the traditional caution of teachers when asked to introduce topics about which they themselves have no special knowledge.

In grammar schools the difficulty has been aggravated by the need for successes in the General Certificate of Education asked for today by many employers who have little idea of the content of a G.C.E. syllabus or its relevance to their own real needs. Each headmaster has to find the balance between satisfying the vocational requirements of children and providing them with a good general education. Continuing scientific and social development require higher standards of attainment in school and result in more and more work being crowded into the existing framework. Attempts to prune existing subjects usually meet with great opposition, and consequently changes in the curriculum do not keep pace with change outside school. "Unrecognized" subjects are not welcomed by many teachers as they take time from the generally "acceptable" subjects.

In the secondary modern schools, examination pressure is not so intense and curriculum experiments are attempted, sometimes through the efforts of local education authorities, but more frequently through the energy and enthusiasm of a particular teacher who is concerned either with the development of teaching methods for existing subjects, or with relating accepted subjects to changing social conditions. Success may go unrecognized for years as the system slowly evolves. The introduction of a completely new subject such as astronautics could also be ignored by the majortiy of schools, unless the initial difficulties were studied and overcome by planning and determination.

The principal obstacle is the shortage of staff. After the war the authorities attempted to solve the problem of overlarge classes by accepting a lower standard of training for teachers, but this has now successfully been resisted by the teacher's own professional organizations who have insisted on the minimum of 3 years of training. The result is that once again many schools are again suffering from an acute shortage of staff.

Then the introduction of astronautics implies the ability of the teachers to understand at least the general principles of spaceflight. Although men and women of high mental calibre and good scientific background have been attracted by the challenge of the modern school, many have been dissuaded from entering the profession by the notoriously low salaries offered. The result of this is a shortage of teachers who will admit to knowledge of even the most elementary scientific principles.

It was with this background in mind that a small education working group, under the chairmanship of L. J. Carter, Secretary of the Society, was set up. Members were recruited from both education and industry, and the group met for the first time in January of this year to study methods of introducing astronautics into schools.

The four main problems were (i) to get time allowed in the curriculum, (ii) to interest teachers in space education, (iii) to provide sound and sufficient background information for teachers, (iv) to maintain interest once it had been stimulated.

It was decided that the first task was the preparation of class notes which could be adapted to cover the age

* *A résumé of some of the work of the Society's Education Working Group.*

† *Head of Mathematics Department, Brays Grove County Secondary School, Harlow, Essex.*

limits of 11 to 15 at all levels of intelligence. It was thought that these notes would be suitable as a basis for a "space fortnight" in which the basic principles of spaceflight could be introduced. Wherever possible they were to be related to existing school work. Ten topics were agreed upon covering all the aspects of spaceflight thought suitable for schoolchildren, and each member of the group undertook the preparation of material on one or two topics that would be sufficient not only for the children but also for the non-specialist teacher. The completed list, as follows, looks formidable for a mere ten lessons.

Topics

(1) Properties of the Atmosphere.
(2) The Solar System.
(3) Escape from Earth.
(4) How Rockets Work.
(5) Rockets Today.
(6) Satellites.
(7) Man in Space.
(8) The Earth and the Moon.
(9) Space Hazards.
(10) The Future.

Appendices for Teachers.

(*a*) Bibliography.
(*b*) List of satellites and space probes.
(*c*) Table of definitions.
(*d*) Table of planetary characteristics.
(*e*) Present-day rockets.
(*f*) History of astronautics.
(*g*) Simple demonstrations.
(*h*) List of things to do.

At this stage the possibility of preparing film strips and wall charts was also investigated, and the method of introducing the proposed Space Fortnight considered. It was decided to give the project a full-scale trial run to test the reactions of teachers and children, before producing these very desirable, but unfortunately, very expensive teaching aids. Accordingly the first Space Fortnight began in late February, in Brays Grove Secondary School, a large mixed bi-lateral school in Harlow New Town with more than 1100 children of all intelligence levels. The lessons were to be given by members of the mathematics department, none of whom had any special knowledge of astronautics. For two weeks, with the exception of classes in active preparation for external examinations, normal mathematics lessons throughout the school were replaced by space lessons.

As time was short each of the six teachers involved studied only one or two topics closely and then selected ten key points of interest around which the lesson could be built. These were expressed in the form of questions which were later duplicated so that every child had a copy before the lessons began. Every teacher had a copy of the notes on all the topics and the amount of work attempted was related to the ability of the particular class.

Here tribute should be paid to this small group of teachers. Although the scheme was presented to them without warning and with little preparation, they responded enthusiastically, modified, adapted, and in some cases re-wrote the notes, made further suggestions and generally did all they could to make the lessons a success.

frontiers of the future

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AIRCRAFT, SPACECRAFT, MISSILES

The reaction of the children was beyond expectation. Some showed themselves to be surprisingly well informed, although the majority had little or no knowledge of the subject. However, their interest was reflected by the flood of newspaper and magazine cuttings which were brought to school. Children from whom homework was usually obtained only with difficulty produced long and surprisingly accurate essays. Naturally there was the usual crop of howlers. For instance, "we are inundated with cosmetic rays"; "a satellite is a body running round and round another body," "spaceflight hallucinations were thought to take the form of pink elephants," and one girl silenced all criticism of man's attempts to get into space by saying crushingly: "If people hadn't done things for the sake of adventure, Columbus would never have discovered Australia."

At the end of the fortnight the children were asked to write a general essay about what they had learnt from the lessons and they were also asked to give their opinions of the value of them. The staff were asked to evaluate and criticize the lesson notes and were also asked for their opinions of the desirability of teaching this subject, both from a personal and educational point of view.

On the whole the essays showed that although the children had absorbed quite a large amount of factual information they had not really grasped the idea of the immensity of space. This criticism was also made by the teachers, who felt that it had been an impossible task to cover all the topics in a fortnight even in outline. In the interests of the experiment the attempt had been made, but no time had been available for discussion, and many lessons remained incomplete. However, in spite of this the lessons had been an unqualified success, and had demonstrated that children of all ages and abilities in secondary schools can effectively be taught the elementary background to astronautics by non-specialist teachers. The essays below have not been chosen for their literary merit, but are of interest as reflecting the attitude of children of different ages and attainment, and their ability to retain factual information at the end of the fortnight.

The first is an unsolicited piece of work from a 11 year-old boy in a stream for backward children. This was in addition to the set work. In fact, none of the information it contains had been given in school.

Space Ship to Venus

The Rushens have launched a Rocket to venus it will tack Three months to Reach it. The Roket will travel for 20,000,000 miles befor Reaching venus.

The Roket was very acuat as it was fired into orbit from the earth. the Roket is carrying instrements to tell the conditions on the *mistery planet*

venus our nearest planet

Venus is the nearest planet to Earth and it is sometimes caled the twin planet that is why it is easy to

The author demonstrates the function of instruments in the nose-cone of a sounding rocket.

"Harlow Citizen"

launch Rockets from earth to it this rocket was carred up by a satterlight all the way professor Lovell is traking it at Jodrell bank Radiow station. This is the bigest station in the world but Just Reasently it faild to track the Russian Rocket professor lovell sais that something must have gon rong with the Rocket.

A French Rat in space

A french siantist sent a whitte French Rat 100 miles out into space her name is Hector then they recovered her alive and in good condition now France is the theird contry to send animails into space. First was Russia then america now France. Hector was recovered by a parachuit.

The next is by a 12 year-old girl of average ability who was asked to write about the lessons.

Astronautics

In our lessons on astronautics the part I liked best was the part about cosmic rays although I liked lots of other things. In the following I will try to tell some of the things we did. First we did a kind of introduction which was quite good and then we learnt about the atmosphere which I liked doing. It was good fun learning the value of the atmosphere to the Earth. We learnt about the three layers, the troposphere, stratosphere and ionosphere and also how it keeps away meteors and atoms.

Next came space hazards which we wrote an essay on. I enjoyed this, and then came sattellites when we learnt some of the things they were used for, communication, meteorogy and navigation. For communication they send sound waves to a satellite which either stores sound and lets it out when wanted or bounces it straight back to earth. In metirology it takes pictures of cloud formation and sends them

back to earth. In navigation they can pinpoint to within a few yards of where they are. The heaviest was a Russian one 6½ tons.

Next was how a rocket works I didn't like this much because it got boring. Then we did the earth and moon system and I liked this very much because it was interesting. It was all about the differences between earth and the moon.

The Solar system was next but we only did a little. I think this would have been very interesting.

I think it was all worthwhile and I enjoyed it very much and I wish we could have done much more.

The 13 year olds were asked to describe a journey to the Moon. This is an example of the work of a boy of above average ability.

A Journey to the Moon

Before starting on a trip to the moon it is necessary to go through extensive training first as there are many conditions in space that you would not experience on earth.

To start with a gigantic rocket is needed, most of which would contain fuel. At the end of it there would be a pressureized cabin in which you would be strapped. The fuel is needed because the rocket has to reach an immediate speed of 7 miles per second to leave the earth's gravity. In the rocket with you, you would need to have air, food and water because once you are in space there is no air.

The cabin in the rockets first used for space flight would be very cramped, so cramped that you could hardly move. The acceleration would be very great and would force you against the back of your seat and might even cause you to black out for a while.

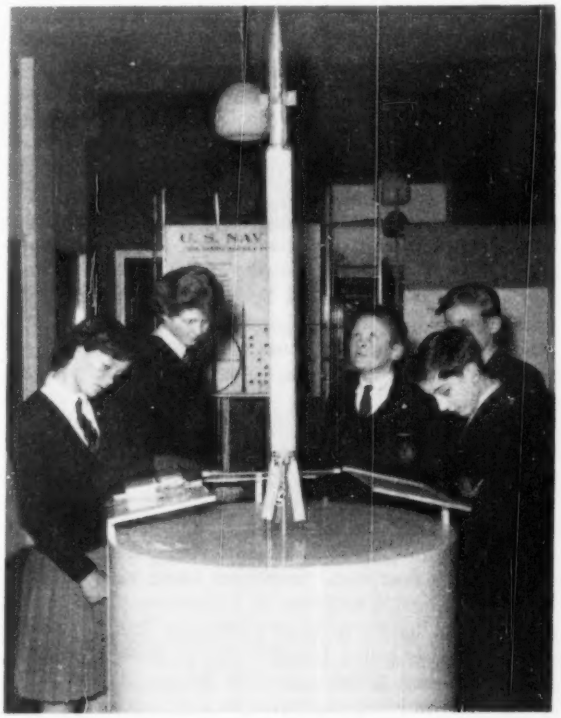
The first layer of atmosphere you would pass through would be the troposphere which is fairly thick and warm and is about ten miles high, this is the air we normally breathe. The next layer is the stratosphere which has a height of about 20 miles and is very cold and thin. In the upper part of this is the Heaviside Layer which is used for bouncing radio waves from one part of the earth to another. The last layer of the atmosphere you pass through is the ionosphere, this is exceedingly cold and extremely thin. It is not known exactly how far it goes upward but it is quite a long way.

Once you leave the force of the earth's gravity you become weightless and if you are not strapped down you float around. Not only you but anything else that isn't fixed.

In outer space there are many hazards such as meteors, cosmic rays or cosmic dust. Very small meteors would make a hole in the side of the ship and all the air would escape and the crew would die. Larger ones would simply wreck the ship. Space ships cannot be shielded from cosmic rays as they easily pass through several inches of steel but the chances of meeting meteors is remote. The only thing to do about cosmic rays is to keep clear of them.

As you approach the moon you would come under the influence of its gravity and be pulled down onto it and crash unless you had some method of decreasing the speed of the ship and gliding down gently. If when you landed you wanted to leave the ship you would have to wear a pressureised suit and lead boots to keep you alive and on the surface of the moon for gravity there is only one sixth of that on earth.
You would find that the moon's surface was very rough with huge craters and high mountains which go up to 30,000 feet in height. It is not known how the craters got there, some people think by volcanic eruptions and others think it was hit by large meteors. The so called seas on the moon are really plains. During a day on the moon which is equivalent to fourteen of our days it is always getting hotter as there is no air to even out the heat. When night comes it gets colder and colder until the day comes again.

This is what it is like on the moon although so far no one has been able to reach it. However I don't think it will be very long before they do for already satellites and sputniks have been sent up with animals



Pupils at Bray Grove County inspect exhibits connected with the U.S. Navy's Exhibition of Small Sounding Rockets.

"*Harlow Citizen*"

in them. Also the Americans have three men in training in preparation for spaceflight so in the near future we should hear of men making their first journey into space.

I think the lessons on space were very interesting and informative. The one I think was best was the one on how a rocket works. I think that we should spend longer on some of the parts as in the time we have had we could not cover all the points.

These three essays have been chosen at random from the hundreds available. Each can be faulted and each represents only one level of attainment. However there is a common element of interest and enthusiasm which was found in a very high proportion of the work attempted.

The reaction of both staff and children was so favourable that a full one-year course of Astronautics and Astronomy is being planned for 1961–62. In the first place it will be for children aged 14–15 in their final year at school, but later it may be possible to begin with third-year boys and girls. Meanwhile interest has been maintained by the loan to the school of two excellent exhibitions—the U.S. Navy's display of meteorological rockets and nose cones used for investigating the properties of the atmosphere, and a collection of wall cards and photographs showing American achievements in space. These are available to any school who wishes to borrow them, from the U.S.I.S., American Embassy, Grosvenor Square.

When the Committee met again on 10 March it was agreed, as a result of the Brays Grove experiment, that instead of teaching notes for a Space Fortnight, a more detailed *Teacher's Guide to Astronautics* should be produced. This would also include information about the introduction of astronautical topics into traditional school subjects such as Art and Craft, English, History, Geography, Modern Languages, and Religious Instruction as well as the obvious Sciences and Mathematics. There would also be articles about Careers in Astronautics, Space Clubs in school, demonstration models and any other matter thought suitable for helping the teacher.

This has now been largely compiled and evaluation by teachers (often B.I.S. Members) in schools up and down the country is being obtained.*

This represents only a first step, and, given adequate support with textbooks, films, film strips, laboratory apparatus and wall charts, it is not unreasonable to hope that within a few years the subject could be introduced into the General Certificate of Education, provided the syllabus was shown to be academically sound. At the moment this is just a thought for the future but there is a strong case to be argued in favour of it both on educational and financial grounds.

* *Teachers who have not yet been approached are invited to write in for details of the scheme.*

Finally it may be of interest to reflect on what the educated child should know about space. Below is a selection from the questions the Brays Grove children answered at the end of their ten lessons. Readers of this magazine will, of course, be able to supply the answers themselves.

The following questions are to be answered during the lessons about space travel.

Introduction

1. What is the science of interplanetary flight called?
2. What is an artificial satellite?
3. What is a space probe?
4. What is the difference between a "hard" and "soft" landing?
5. What is meant by re-entry?
6. What are the three main differences between space travel and ordinary travel?
   (*a*)
   (*b*)
   (*c*)
7. What is the difference between space exploration and the exploration of our own world?

The Atmosphere

1. What is the value of the atmosphere for the Earth?
   (*a*)
   (*b*)
2. What is it made of and what keeps it there?
3. What two gases are most used by plants and animals?
4. What are the names of the main layers of the atmosphere?
   (*a*) (*b*) (*c*)
5. Briefly describe the main features of each layer, *i.e.*, density, thickness, temp., etc.
   (*a*)
   (*b*)
   (*c*)
6. Draw a sketch of the Earth surrounded by its atmosphere.
7. Why is it difficult for man to leave the atmosphere and stay alive?

How a Rocket Works

1. Draw a diagram illustrating the principle of a rocket motor.
2. Draw a diagram of a modern large rocket.
3. What is Newton's third law of motion? Give some simple examples of how it works
4. The rocket is the ideal interplanetary vehicle. Why?
5. What are two chemicals used to make a rocket work?
6. What is the mixture used in a solid fuel rocket called?
7. What are the advantages of liquid fuel?

8. What is regenerative cooling?
9. How does mono-propellent fuel work?
10. Name three other kinds of rockets giving the chief advantages of each

Earth—Moon System

1. How far away is the Moon?
2. How long does it take the Moon to circle the Earth?
3. How fast does the Moon travel?
4. Draw a diagram of an eclipse
5. If you could jump *x* feet on Earth, how high could you jump on the Moon?
6. How long is a "day" on the Moon?
7. What are the seas?
8. What atmosphere is there on the Moon?
9. What are the probable causes of craters?
10. How high are the mountains on the Moon?

Question and Answer

I am venturing to make an enquiry regarding two astronomical (and astronautical) terms. If an object, *e.g.*, a rocket-head, is running in freefall around the Earth on an elliptical course, the words apogee and perigee have come into use to mark the furthermost and nearest points respectively in relation to the Earth. Now "gee" means "Earth," and I am writing to ask if the B.I.S. has made any ruling for a case where a similar passage is around, say, Venus or Saturn or Jupiter. Does one still say "apo*gee*" and "peri*gee*"?* Hoping to hear from you soon on this point.—Yours etc.,

P. Bown.

Perigee and apogee are words of Greek origin, meaning those points on the path of a celestial body which are respectively nearest and furthest from the Earth. The words were carried in the context of the Ptolemaic universe, in which all heavenly bodies are believed to rotate around the Earth. The philological derivations of these words, according to Webster's Dictionary, are:

"Apogee"—from the French, "apogée"—from the Latin "apogaeum"—from the Greek "apogaios," formed from "apo" [from] + "gé" [earth]. "Perigee"—from the French "périgée"—from the Latin "perigeum"—from the Greek perigeios, formed from "peri" [near] + "gé" [earth].

If Mr. Bown wants to be accurate in the use of these words, he has two alternatives:

(1) *The Greek word "gé" must be replaced by a Greek word for the astronomical body around which the particle (space-vehicle, satellite, etc.) is moving, the correct declensions of course being observed (Apoven, Perisat, etc., are just not good enough!)*

(2) *Replace the word (gé) by some Greek word for "focus," or "centre," to give the words a wider application.*

I am fully sympathetic to Mr. Bown's query; there is as little excuse for philological laziness and inaccuracy as for scientific laziness and inaccuracy.—Ray Cruddace.

* *Of course, it wouldn't be:—Apoven and Periven; Aposat and Perisat; Apojove and Perijove?*

Correspondence

Sir,—E. G. D. Andrews' paper "British Participation in Space Research" (March, 1961, *Spaceflight*) makes me regret my absence when it was presented to the B.I.S. as a November, 1960, lecture. Not only does the paper strike me as an exceptionally cogent summary of the reasons why Britain should engage in astronautical projects, but it also demonstrates that much useful and remunerative work could be done with hardware either in existence or available as the outcome of fairly short-term and not very costly development.

As Mr. Andrews points out, one of the most commercially attractive and urgently utilitarian schemes is the establishment of radio relay satellites. America is already prosecuting this subject, whilst our own G.P.O. is apparently impressed with the possibilities . . . as of course it should be, for the Commonwealth more than any other group of nations needs first-class intercommunication for commercial, political and sociological reasons.

However, I take the liberty of not agreeing with Mr. Andrews that active satellites are likely to be better than passive ones. Certainly the opposite opinion seems to be gaining ground in the U.S.; for instance, *Electronics*, 27 January, where the unreliability of electronic gear is bemoaned and a new type of balloon reflector is discussed. Though doubtless electronic reliability will be improved, it is scarcely likely ever to compete successfully with the absolute infallibility of passive reflectors—provided, of course, that if (say) a balloon is used it retains its original form indefinitely. Surely this is no unsuperable problem; in fact it seems strange that unstable forms *have* been employed. Again, whilst active satellites have channel limitations, passive satellites could handle a virtually unlimited number of "lines." A disadvantage of passive relays is that very high power terrestrially-based transmitters would be needed for some services. Nonetheless, this is only an objection if one persists in thinking in terms of existing transmitters. In astronautical hardware large-scale thinking is imperative—in astronautical electronics, likewise. If to inaugurate a reliable passive communications system all that is required is more powerful transmitters, then let us not be scared by magnitude. At very least ganged units of normal rating

could be used. On the other hand, power outputs can surely be raised and gargantuan steerable antennas wait for no new technological advance. Besides, it is cheapest in the long run to have the most complex equipment on Earth, where one can get at it for maintenance and repair. . . . In short, I suggest that the whole subject of communication by means of passive satellites should be immediately and energetically pursued by Britain. Here at least there is ample scope for profitable new ideas. . . . In fact, the encouragement of independent new ideas and better methods (often needing nothing more costly than a sheet of paper and a pencil guided by a good brain), is a prime essential to success and cheap progress in astronautics. You do not have to be backed by millions of pounds before you can think.

Mr. Andrews makes some interesting observations about launching site facilities already available to the U.K. It really is a pity that Woomera was shortsightedly located in an undesirable latitude and wrongly oriented. Certainly a new range will be needed, in Commonwealth-controlled territory.

This recalls to my mind pre-war B.I.S. discussions, in which the most favoured launching site was the Andean Lake Titicaca, partly in Bolivia, partly in Peru, lying in 16 S., area 3200 sq. miles, altitude 12,500 ft. This lake is accessible by railway from the Pacific coast, and it has convenient islands—though as a matter of fact (and shades of Polaris!) the B.I.S. spaceship was to be launched from a caisson submerged in the water, the lake forming an easily patrolled security area. The reasons for a high-level launch were precisely those given by Mr. Andrews (who however favours the locality of Quito, on the Equator), except that the slightly lesser gravity attending a high-level launch was deemed another worth-while advantage. It may be added that a few other large lakes exist in this region.

But Titicaca is subject to high winds and violent storms—and the Andes are not in Commonwealth territory. Second B.I.S. preference was either Mount Kilimanjaro (19,324 ft.) or, like Mr. Andrews' selection, Mount Kenya (17,040 ft.), both very near 0° latitude, and therefore especially suitable for launching equatorial satellites.

There is, however, a fatal objection to having an astronautical range in Africa—its political instability. Regretfully, I also conclude that India and Ceylon (the west and south coasts of which are in the tropics, with ample clearway east and south), may not be acceptable long-term risks. Indeed, an island—and a fairly small one at that—seems better for all-round security than is a continental range-head. Furthermore, I feel it desirable that the island should be indisputably under either U.K. or Australian or New Zealand control.

Readers of *Spaceflight* may like to make their own choice, bearing in mind that the island should be in the tropics and have as much down-range clearway as possible over a large arc eastwards. One area satisfying these requirements lies in the Pacific, 0° to 10° S., east of Bougainville, the principal groups of islands being (in order west to east) the Solomons, the Gilbert and Ellice and the Phoenix Islands. . Here, apart from smallish islands, some of which might be useful for tracking stations, there is ample clearway over the 180° north—east—south arc. Two other island possibilities, this time in the Atlantic, are Ascension and St. Helena. Minimum clearway east to north of Ascension is some 1200 miles, greater still from St. Helena. South-east to south the clearway is unlimited, right over the Antarctic continent

Yours, etc.,

H. E. Ross.

Sir,—Just a few thoughts in connection with H. E. Ross' review of my book and the May issue in general.

(1) Re: *Water on the Moon*. It appears that my idea of water being bottled up beneath the lunar surface by a permafrost seal has received some unexpected support.

Dr. T. Gold, now of Cornell University, Ithaca, N.Y., presented a paper "Permafrost on the Moon" at a meeting of the American Geophysical Union in Washington on 18–21 April, 1961. I have the abstract which states: "The possibility is discussed that water is bottled up beneath the Moon's surface. . . . The question is raised whether large amounts of water could be contained in the Moon, thus accounting for its low density."

It also appears that somewhat similar ideas have been put forward in an article by J. Gilvany in 10 December, 1960, issue of *Nature*, which I have not seen.

(2) I was interested to read about "Electrical Rocket Propulsion," for I appear to have been the first to suggest something like the arc rocket—only I thought of a wreath of electric sparks, which would yield still higher temperatures, outside the rocket exhaust. See page 93, "Our Neighbour Worlds," first published in 1952.

(3) I see that your correspondent G. T. Kinglsey seems to insinuate that my "grids" are sometimes based on two craters. This shows that he knows very little about this, which may present some inconveniences in writing about it, for, firstly, my grid lines are not "based" on craters, although some craters do fall in with them; secondly, a cursory glance at the grid map in my recent "Surface of the Moon" will disclose no case of a grid line determined by three, let alone two, craters. The whole point of the grids is that crater chains and the walls of walled plains are so often aligned with faults and fractures.

Yours, etc.,

V. Axel Firsoff.

Sir,—I was sad indeed to see the units of specific impulse quoted yet again in *seconds*.*

It is not permissible to cancel a force (thrust) with a mass. The correct units of specific impulse are

$$\frac{\text{Lb. Sec.}}{\text{lb.}}$$

where Lb. represents pounds force, and lb. represents pounds mass.

Yours, etc.,

S. W. Greenwood.

* *Spaceflight*, *May*, 1961, *page* 112.

New Radio-Telescope

An Australian radio-physicist has been selected to design the aerial for the world's most sensitive radio-telescope. The telescope, which is to be a joint venture by the Dutch and Belgian Governments, will cost about £1 million.

Professor Christiansen, Professor of Electrical Engineering at Sydney University and a former member of the Radio-Physics Division of Australia's Scientific and Industrial Research Organization, said the radio-telescope he will design would resemble a huge cross, each arm being 2 miles long. It would be about twenty times more discriminating than the radio-telescope at Jodrell Bank.

THE BRITISH INTERPLANETARY SOCIETY

THE BRITISH INTERPLANETARY SOCIETY was founded in 1933 to promote the development of astronautics—interplanetary exploration and communication—by the study of rocket engineering, space medicine, astronomy, navigation, astrionics and other associated sciences. Its membership is international and includes most workers prominent in these fields.

The main work of the Society consists in the publication of two periodicals (free to all members); in the publication of books and monographs; and the organization of scientific and technical meetings. In addition to symposia and meetings at which original research papers are presented, lectures, exhibitions, visits to research establishments and film shows are held to explain to the lay public the progress that is being made in astronautics and the ultimate implications to human society of the crossing of space.

PRIVILEGES OF MEMBERSHIP

All members of the Society are entitled to the following privileges:

(*a*) To receive copies of the *Journal* (six issues per year), which contains research papers, reports of lectures, news items, announcements, reviews and abstracts of all important publications on astronautical subjects.

(*b*) To receive copies of *Spaceflight*, a quarterly non-technical magazine, and other publications issued from time to time.

(*c*) To attend all lectures, meetings, symposia, exhibitions, and film shows arranged by the Society.

GRADES OF MEMBERSHIP

There are four grades of membership of the Society: Fellowship, Associate Fellowship, Senior Membership and Membership.

Fellowship

The general requirements for Fellowship are any one of the following:

(*a*) A recognized University degree in Science, Mathematics, Engineering or Medicine, *plus* five years' relevant scientific, industrial or other professional experience.

(*b*) Corporate Membership of a recognized professional Institution.

(*c*) Considerable contributions to the development of astronautics.

Associate Fellowship

To be eligible for admission as an Associate Fellow, an applicant shall possess at least one of the following qualifications:

(*a*) A recognized University degree in Science, Mathematics, Engineering, or Medicine.

(*b*) Graduateship of a recognized professional institution.

(*c*) Higher National Certificate, or an equivalent.

(*d*) An examination qualification equivalent to Inter. B.Sc. or Ordinary National Certificate, *plus* five years' relevant scientific or industrial experience.

Applicants for election to Associate Fellowship under Clause (*d*) above must not be less than 25 years of age. Applicants for election under other clauses must be over the age of 21 years.

Senior Membership

Applicants for this grade must have been members of the Society for a period of seven years.

Membership

No technical or other qualification is required for membership, as this grade is particularly intended for the large body of persons who realize the possibilities of astronautics and wish to keep in touch with current developments. There are no age limits.

FEES

Subscriptions are payable on 1 January in each year, at the following rates:

Fellows, Associate Fellows and Senior Members, £3 3s. 0d.; Members, £2 2s. 0d. (under 21, £1 11s. 6d.).

An entrance fee of 10s. 6d. is also payable with all applications.

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EQUIPMENT ENGINEERS

(Ref. EQ/ENG.) For responsible installation, check-out and technical maintenance posts within the radar, digital, display, and other sub-systems also in the data handling and communications sub-system for men with corresponding experience.
The right men will be given opportunities to acquire a thorough sub-system background, be capable of handling equipment technicalities. Qualifications—HNC or a degree are a desirable asset, and also a minimum of 5 years' practical experience.

EQUIPMENT SPECIALISTS

(Ref. EQ/SP) To lead technicians on the floor throughout installation and become skilled in technical trouble-shooting at sub-system level and assisting the engineers with higher order technical problems. The men we need will be technically qualified with ability to diagnose equipment troubles and should have over 5 years' experience in systems work of this type.

TECHNICIANS "A"

(Ref. TECH. A) For installation and integration and to assist Equipment Specialists with continuous maintenance of BMEWS electronic and electro-mechanical equipment. They will be able to use complex schematics, be familiar with electronic cabinet systems and advanced types of electronic test equipment.
Qualifications required include technical training to ONC level, plus minimum 4 years' industrial or military electronic experience.

TECHNICIANS "B"

(Ref. TECH. B) These posts provide good openings for skilled and semi-skilled electronic wiremen who have received some formal technical training. They will participate in complex installation work in all equipment areas and be given a training course for technician grades prior to the operation and maintenance phase, with good possibilities of promotion.
Wide knowledge of basic electronic components and several years of practical experience on high grade electronic equipment wiring is required.

Our selection demands are exacting, our techniques are up to the minute. We can arrange informal interviews to suit you—in your locality—in the evenings—at weekends. A letter to the address below, summarising your technical training and experience in your areas of interest will bring you an application form and could lead to an absorbing new career.
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